<u>***Reorganization on Nov. 1***</u>

The Big Shuffle: What It Means

You're probably not alone if you've raised the question "Why the big shuffle?"

A major reorganization of Sandia, announced Sept. 29, moves many employees to other organizations, and establishes a new vice presidency (9000 — Exploratory Systems) and a new directorate (1400 — Computer Sciences and Mathematics). All this happens on Nov. 1. So why the changes?

First and foremost, Sandia is not a static organization. If you've been around the Labs for any length of time, you probably remember several major shuffles in the past. The Labs moves with the times, and that's one of the key reasons for changes at this juncture, according to President Irwin Welber.

"We continue to look in new directions, explore new technologies, and make decisions as to how Sandia can do the very best job for DOE and for the country," Welber says. "To make those kinds of decisions, you have to take a long-range view — not just at how things will be a year or two from now.

"From time to time, we need a reorganization to bring together groups with similar missions and objectives," he continues. "Their activities may not have meshed in the past, but now they do. And we have many people, who, as a result of their experience in either the weapons or energy programs, can bring considerable talent to new activities such as arms control verification studies — work that will now be concentrated in the 9000 organization. In fact, the number of people working on verification in 9000 may make it the single largest program in the country focused on that technology."

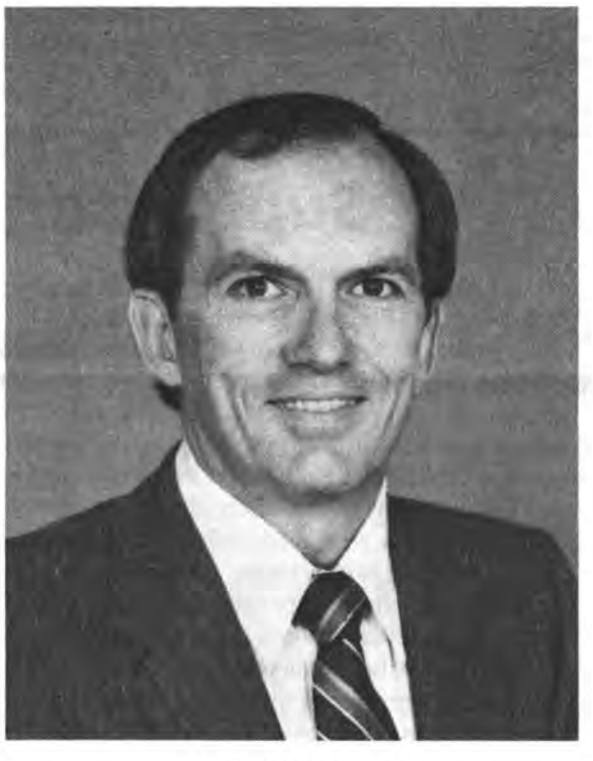
The 9000 vice presidency will bring together what is now Org. 300 (Systems Studies), Org. 5300 (Instrumentation Systems), and three departments in 1600 (Systems Sciences). Soon-to-be VP 9000 Roger Hagengruber (300) says a priority for the new organization will be to come up with a comprehensive plan for the Labs on how best to approach and manage activities in new areas that have tremendous growth potential over the next several decades.

"We'll be looking at a variety of new activities — arms control verification, foreign technology and threat assessment, and advanced systems technology for both nuclear and conventional weapons systems," says Roger. "All of these areas are expanding. How fast they should or can expand, and what are the best directions for future growth: These are the difficult and important questions we will need to address. We at Sandia should be prepared to respond to changing national priorities in these areas.

"And more than that, we want to be able to offer — to DOE and to the country — an asset that one day could prove very valuable: a resource group that can supply expert comparative judgments on future

(Continued on Page Four)

ORVAL JONES (20)



DAN HARTLEY (6000)

ROGER HAGENGRUBER (9000)

LAB NEWS

VOL. 38, NO. 20 SANDIA NATIONAL LABORATORIES OCTOBER 10, 1986

Save This!

This issue of LAB NEWS contains all the info you'll need to enjoy Family Day 86 — tour maps, exhibits, bus schedules, parking, refreshment areas, etc.

In addition, there are stories on 40 years of Sandia contributions to the nation's nuclear defense. They're worth reading. They're worth saving.

<u>***Hail & Fare Well, Tom Cook***</u>

A Tribute to Tom, His Talent, His Triumphs

Few people have been at Sandia so long, climbed the management ladder so high, and left such an indelible mark on the place — and on the nation's nuclear deterrent — as Tom Cook. Tom's retiring, after 35 years of service, on Oct. 31.

Since 1982, Tom's been the executive vice president over the Labs' defense, component development, energy, and Livermore programs. When the LAB NEWS interviewed him last month, Tom noted that "Sandia has achieved a status of excellence both in very high scientific circles and in very capable development circles." Self-effacing as always, he quickly added, "A lot of us have been involved with that [journey to excellence]; we've come a long way since 1951, when Sandia was sometimes hiring people off the street just to get the job done."

Tom himself was not one of those "hired off the street." He was among the first Sandia new-hires with a PhD (in physics).

He was not a typical new-hire. Sandia, it must

(Continued on Page Six)

Antojitos

Happy Fiscal New Year! Like the ordinary one in January, which comes right after the Christmas lull, October marks a revival at Sandia. September is the "use it or lose it" month for vacations, and judging by the paucity of cars in the parking lots, we had more users than losers. Management encourages us, of course, to use up our vacation early so those who are here in late September won't get lonely. Two observations on that phenomenon: 1. Ever notice how much like a wage slave you feel once you've used up all your vacation days? There's nothing worse than to wake up every day knowing that you absolutely have to go to work. 2. Ever notice how few managers are on the premises in late September?

So October means that everyone's back at work, budgets are as large as they're going to get, and the task proceeds on course. Well, it does in a normal October. This year, however, we're faced with two Sandia-shaking events: 1. Family Day. 2. Tom Cook's retirement. Both are demanding some extra attention. And both are worth it --

If you haven't decided whether to come out for Family Day on the 18th, I encourage you to make the effort. Wax the car, cut the firewood, wash the summer's accumulation of dishes on the 25th. Come out and give your spouse and/or progeny some idea of where you spend much of your waking time and what you do when you're here.

And if you're not sure whether Tom Cook has had some effect on what you're doing at Sandia, read our story bidding him farewell. You'll probably find that, one way or another, Tom had a hand in it.

•BH

* * *

Obra de común, obra de ningún. (Spanish: Everybody's business is nobody's business.)

volunteers in action — VIA

Here are a couple of current opportunities for employees, retirees, and family members. If you would like more information, call Karen Shane (3163) on 4-3268.

MAYOR'S COMMISSION ON ADULT LITERACY is holding a training session on Oct. 17-18 for tutors. Would you like to commit an hour a week for the next year to teach someone to read?

ALBUQUERQUE RAPE CRISIS CENTER'S training program for victim advocates will be held on Oct. 16, 18, 21, 23, and 25. Would you be interested in volunteering with this agency?

Open House for Tom Cook

Sandians who have worked with Tom over the years are invited to the open house the Labs is holding in his honor. It's from 2 to 4 p.m. on Oct. 27 in the Cafeteria (Bldg. 861). Refreshments will be served.

LOOKS GOOD, even if it *is* on backwards, Pete Egan (3330) tells Lori Foust (3313) as they try out their new TLC T-shirts. The shirts, aqua with a black TLC logo front and back (obviously, the back one's larger!), are on sale for $7 at the LAB NEWS office, Bldg. 814. Pete's the fitness activity coordinator for the TLC (Total Life Concept) program, and Lori handles TLC computer programming.

LAB NEWS

Published Fortnightly on Fridays

SANDIA NATIONAL LABORATORIES

An Equal Opportunity Employer

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AMARILLO, TEXAS

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Supervisory Appointments

LARRY SCOTT to supervisor of Electromagnetic Testing Division I 7554, effective Sept. 1.

Larry has been a member of Electromagnetic Testing Division II 7555 since he joined Sandia in April 1984. He was at Bell Labs in Merrimac Valley before attending Harvard University where he earned his MS and PhD in applied physics. He has a BS in EE from the University of Arizona. He spent one summer as a research fellow at Los Alamos. After receiving his doctorate, Larry was a research and teaching fellow in applied physics at Harvard for two years. He then worked as manager of the Albuquerque office for Mission Research Corp. of Santa Barbara before coming to Sandia. He served on the Mission Research Corp. Board of Directors for five years.

Larry is a member of Phi Kappa Phi, Tau Beta Pi, and Sigma Xi, and is a senior member of IEEE. In 1969, Larry received the IEEE G-AP Best Paper of the Year Award for his paper on using an antenna for a diagnostic probe in a gaseous plasma entitled, "A Short Cylindrical Antenna as a Diagnostic Probe for Measuring Collision Frequencies in a Collision-Dominated Non-Maxwellian Plasma." He served for three years as an officer of the local IEEE G-AP Chapter.

Larry has served on the board of directors of his church since 1978. In his spare time, he is involved in training overseas missionaries to use PC-style computer equipment more effectively.

His hobbies include microcomputers, amateur radio, and camping. He is chairman of the DEC PC Local User Group (DECPCLUG).

Larry and his wife Enid have three children and live in the NE Heights.

* * *

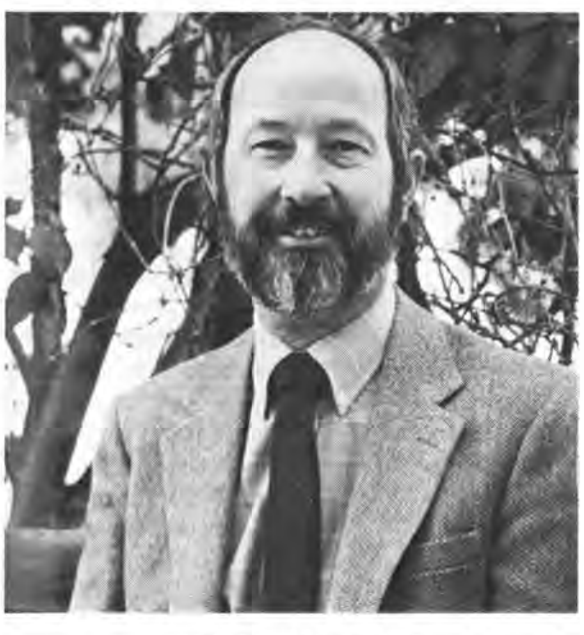
BILL LOVEJOY to supervisor of CRM Program Development/Management Division 2151, effective July 16.

Bill has worked in the program development and management area since he joined Sandia in October 1983. Before coming to Sandia, he served 21 years in the U.S. Army, spending the majority of that time in program management assignments.

Bill has a BS in industrial engineering from Georgia Tech and an MS in systems engineering from the University of Arizona.

In his spare time, he enjoys camping and gardening. While Bill was in the Army, he and his family enjoyed living in different countries and working with different cultures, primarily in the Orient.

Bill and his wife Harriet live in the NE Heights. Their daughter Lee Anne is doing graduate study in Mons, Belgium.



LARRY SCOTT (7554)

BILL LOVEJOY (2151)

'CTOBER RETIREES at Sandia Livermore (front to back): Dee Allen (8184), Jim Ackerman (8161), Ralph Kelley (DMTS, 8266), and Carlton Scott (8241). Not shown, Gordon Bennett (8186).

Supervisory Appointment

PETER MATTERN to director of Combustion and Applied Research 8300, effective Nov. 1.

His career began at Brookhaven National Laboratories where he was a postdoctoral candidate and then staff member from 1965-71. In 1971 he joined Sandia at Livermore, where his first assignment was to work on radiation effects in glass. He next moved to Systems Studies where he studied the use of large-scale computers in the U.S. weapons complex.

In 1977 he was named supervisor of the Applied Physics Division; the group worked on Basic Energy Sciences programs in combustion and materials science. In 1982 he was promoted to department manager of Combustion Sciences.

Peter earned his BS at Yale University in 1961 and a PhD from Cornell in 1965; both degrees are in physics.

He and his wife Nancy have three daughters and live in Livermore. Peter is active in the Combustion Institute, American Physical Society,and the Livermore Science Advisory Council. His outside interests include his girls' age-group soccer, and swimming, squash, tennis, photography, and raising roses.

PETER MATTERN (8300)

WHEN TOM COOK became Vice President of Sandia Livermore in 1968, he didn't know he would later consider the 14 years he spent there as the highlight of his 35-year Sandia career. Here, retiring Livermore VP Bernie Biggs offers his chair to Tom as then-President John Hornbeck assists in the transition.

SANDIA LIVERMORE NEWS

VOL. 38, NO. 20 SANDIA NATIONAL LABORATORIES OCTOBER 10, 1986

Most Exciting LEAP Kickoff Ever

$135,000: Here We Come!

With an ambitious goal of $135,000, the 1986 LEAP (Livermore Employees Assistance Plan) committee is staging the most exciting kickoff and Agencies' Faire ever on Tuesday, Oct. 14.

Designed to encourage Sandia Livermore employees to give generously next week, the noontime events begin with the popular run/walk up the hill and back. Survivors will then enjoy the effervescent English disc jockey "Wolfman Wavell-Smith" playing hit music fitting this year's theme, "The Nifty Fifties."

But that's not all: There will be a personal appearance, on stage, in full costume, of "Little Eugene & The Thunderbirds" (four 8000 directors). And they'll sing some of the oldies but goodies! Then there's a classic car show, hula hoop and Fifties dress-up dance contests, and the same hot dog and soft drink offerings as last year.

The hula hoop contest will pit division supervisors (at least those with no back problems) against one another, and a bubble gum-blowing competition will prove which department manager has the most wind. The other new event is the dance contest, which involves two couples from each directorate in Fifties outfits attempting to emulate Dick Clark's American Bandstand shakers and twisters. There may even be dancers from the Mouseketeers if they can find their mouse ear hats!

Drawings will be held among employees willing to pledge a "Fair Share" (0.6 percent of your pay) for such prizes as a month's free parking in the Vice President's space, T-shirts, posters, and more.

The center of activity will be the LEAP Agencies' Faire on the computing center deck outside; some 27 local human service agencies plus the United Way and California Combined Health Agencies will set up tables to explain their programs and encourage voluntarism among Sandians.

Comments by the human service agencies participating last year indicated they were not only pleased with the opportunity to explain their operations to employees on site but also gained a lot from meeting other agency representatives and exchanging literature.

LEAP chairman Jim Woodard (8432) encourages Sandians to take an active interest in visiting agency representatives as well as to enjoy the Faire's fun events: "We're making this year's LEAP kickoff as eventful and enticing as we can, hoping that people will be motivated by these good times to follow the 1986 slogan 'Make Your Actions Count!' "

Directorate meetings with all employees will be held Oct. 15 and 16 in the auditorium to explain the pledging process, which will enable employees to select the contribution plan of their choice to help reach the 1986 goal of $135,000.

Take Note

Karen Quock (8261) has been elected president of the Livermore Valley Charter Chapter of the American Businesswomen's Association. She has been a member of the group since 1979 and was named 1986 Woman of the Year by the chapter this past February. Karen has held several offices in the local unit over the past seven years. Elected vice president this year was Arline Harrell (8400), who has been an ABWA local chapter member since 1977.

Continued from Page One

Reorganization

options and directions to follow as priorities change. The job before us is a big one; I think we can safely say it will be ever-changing — a dynamic and exciting challenge. And we'll need support from many different areas at the Labs to get the job done."

Roger says the 9000 organization will rely on expertise developed in both the weapons and energy programs, which have been priority activities at the Labs for some time. "We already draw heavily on expertise in all of the other Sandia organizations," he says. "I expect that the trend toward widespread Sandia participation in areas where Organization 9000 has systems responsibility will continue."

Establishment of the Computer Sciences and Mathematics directorate (1400) reflects top management's belief that in the future the Labs will depend more and more on electronic computation and processing, embedded computing, artificial intelligence, computer science, and electronic engineering, says 1000 VP Bill Brinkman. "Sandia needs a better interface to research in these areas," says Bill. "Such interfaces are only developed by active participation in the research itself."

Gus Simmons (1640), who will head the Applied Mathematics Department in the new directorate, says Sandia needs a "critical mass of experts" in the fields of computer science, applied mathematics, and engineering science. "There's a renaissance going on in the field of analytical sciences," says Gus. "I'm excited that Sandia will now have an organization specifically chartered to do that kind of work. Not only should we be able to attract some of the most talented people in the country to help with the task, but — given the focus that the new directorate provides — we should be able to work with some of the top people from top schools."

Call it what you will — zeroing in on the action, going with the flow. One thing is certain: Sandia will continue to look to the future, and to posture itself to meet new challenges. "Change is not an end in itself," says Irwin Welber. "But change is sometimes necessary to maintain a dynamic, forward-looking organization — one of which we can all be proud."

•PW

Bertholf Named Director of Computing 2600

Larry Bertholf, currently manager of Exploratory Systems Department 8430, has been named to succeed Ron Detry as director of Computing 2600, effective Nov. 1.

Larry joined Sandia in Albuquerque in 1966 as a staff member in the Computational Physics and Mechanics Division. He was promoted to division supervisor in 1969. In 1980, he became supervisor of the Scientific Network Design Division. He was promoted to manager of the Applied Mechanics Department at Livermore in 1982. Two years later he transferred to the Exploratory Systems Department.

"I'm looking forward to returning to Albuquerque, and visiting friends we left behind four and a half years ago," he says.

Originally a shock wave physicist, Larry is looking forward to his new position. "I came to Sandia because I felt it was the place I could learn quickly about applied mechanics and shock waves. That proved to be true. And now I'm looking forward to learning about my new job."

Larry's educational background includes a BS in ME and a PhD in engineering science, both from Washington State University.

Before he joined Sandia, Larry was an instructor at Washington State. He is a member of the American Society of Mechanical Engineers. Outside the workplace, Larry has achieved the standing of life master in duplicate bridge. He and his wife Carol have two children.

Shifts in Top Management

Orval Jones, currently Vice President of Defense Programs 5000, has been named Executive Vice President 20. Sandia's Board of Directors selected Orval to fill the position vacated by Tom Cook, who will retire Oct. 31.

"I'll have to work hard to fill Tom's shoes," Orval says. "I'll miss his wealth of knowledge and sense of where we have been and where we are going."

Orval joined Sandia in 1961. "My good fortune was to join Sandia as it began its move toward the premier high-technology engineering R&D laboratory it is today," he says. "From a single-purpose organization devoted to what continues to be our overriding main mission — ordnance engineering of nuclear weapons — we have become a multiprogram national laboratory contributing to national security over a broad front. I see a bright future for Sandia because of the 'can do' ethic of our staff and our proven reputation for successful accomplishment in high-risk, urgent — and often sensitive — government programs."

Before coming to Sandia, he was a staff member from 1956 to 1957 at Hughes Aircraft in Culver City, Calif., and was a research engineer at the Hydrodynamics Laboratory of the California Institute of Technology in 1960 when he found out about Sandia. "I'd never heard of Sandia until Mel Merritt [400], recruiting for Sandia, stopped by the lab and asked me what I wanted to do. I was going to Los Alamos for an interview, and Mel suggested that I stop at Sandia on the way."

He has a BS in ME from Colorado State University, and an MS and PhD from the California Institute of Technology in the same field.

Orval, a Colorado native, thought a desert of shifting sand began at the Colorado/New Mexico border. "We ran into a dust storm at Gallup that followed us along our route to Albuquerque. When we got up the next morning, the air was clear and sharp." The Jones family has been here ever since.

Orval chose Sandia over other companies he'd interviewed at because, he says, "Sandia made me feel that it really wanted *me* and not just my PhD." Before deciding to work at Sandia, Orval considered teaching, doing research, and getting research papers published. "I got my PhD because I enjoyed teaching," he says. "After I'd been at Sandia a year or two, though, I thought this was great. I've never really considered leaving."

Orval was named supervisor of the Shock Wave Physics Research Division in 1964. He was promoted to manager of the Physical Research Department in 1968 and was named director of Solid State Sciences Research in 1971. He was director of Nuclear Security Systems from 1974 to 1977, after which he became director of Nuclear Waste and Environmental Programs. He became director of Engineering Sciences 5500 in 1978. He was named Vice President 7000 in 1982 and became Vice President of Defense Programs 5000 in 1983.

LARRY BERTHOLF (2600)

"I never envisioned moving into management," he says. "I consider the real strengths of Sandia to be the change and diversity of work here. There's plenty of physical science and engineering work to do."

Orval sees the opportunities to move from job to job and the technical education available to employees as benefits of working at Sandia. "Job announcements and the bidding system, In-Hours classes, and technical education programs make people feel good about moving into other jobs, make it easy to move around," he says. "You can move into another job and keep on growing. The variety of job assignments is stimulating."

Orval is a member of the American Physical Society, the American Society of Mechanical Engineers, American Association for the Advancement of Science, Sigma Xi, and the Chemical & Nuclear Engineering Advisory Committee at UNM.

Roger Hagengruber, currently director of Systems Studies 300, will become Vice President of the newly created Exploratory Systems Organization 9000, effective Nov. 1.

Before coming to Sandia in 1972, Roger was an assistant professor of physics at Western Michigan University. He had two reasons for leaving teaching to come to Sandia. "The environment in both Livermore and Albuquerque was one reason," he says. "Both places were obviously great places to live and every person I spoke with was enthusiastic about Sandia and his or her work. Clearly, their enthusiasm was contagious. I quickly became infected and I haven't been able to shake the disease."

The second reason was related to his interests. "I enjoyed teaching very much," he says. "But, I wanted an opportunity to work on practical things, to build systems that could change the future. The focus on national security and the unique opportunity to be involved in both weapons and verification made Sandia an irresistible match to my interests."

In 1975, he was promoted to supervisor of a systems research division. He was manager of Systems Research Department 310 from 1980 until 1984 when he became director of Systems Studies.

"When I came to Sandia, I wanted to make a substantive contribution in the area of national security, and to do it in a balanced way, taking into consideration both our weapon needs and our opportunities for negotiations," he says. "There have been numerous opportunities to do that.

"Also, Sandia has a special 'can do,' introspective, self-critical, and practical character that I wanted to help sustain, to contribute to in some meaningful way," he continues. "One of my greatest satisfactions is that I have been able to make such contributions at the Labs."

Roger has a BS with majors in physics and in American institutions, an MS in physics, and a PhD in experimental nuclear physics from the University of Wisconsin. He is a member of the American Physical Society, and serves as an adjunct professor of political science at UNM.

Outside the Labs, Roger has had a long involvement with youth sports — he was a Little League manager and coach for nine years — in the Albuquerque community.

Dan Hartley, currently director of Combustion and Applied Research 8300, has been named Vice

(Continued on Next Page)

Coming Up Next Saturday

Family Day: What You Need to Know

Family Day at Sandia National Laboratories, Albuquerque, will be held on Saturday, Oct. 18, 1986, from 9 a.m. to 4 p.m. No classified operations are planned at the Laboratories on that day.

Don't forget your badge and (Access Control-approved) guest list.

A souvenir folder will be given to each visitor entering a technical area. The folder contains information about exhibits and demonstrations — and a map of the open security areas where exhibits are located.

Hand-carried items may be subject to searches at entrances and exits.

Kirtland AFB Entry Gates

The Wyoming and Gibson gates will be open around the clock, as usual. The Eubank gate will be open from 7:30 a.m. to 5 p.m.

Sandia Entry Gates

Many, but not all, Sandia gates will be open on Family Day.

In Area I: gates 1, 2, 4, 6, 7, 8, 9, 10, 14, 15, and 16, from 9 a.m. to 4 p.m. Gate 20 will be open from 10 a.m. to 12 noon.

In Area II: gate B-1, from 10 a.m. to 12 noon.

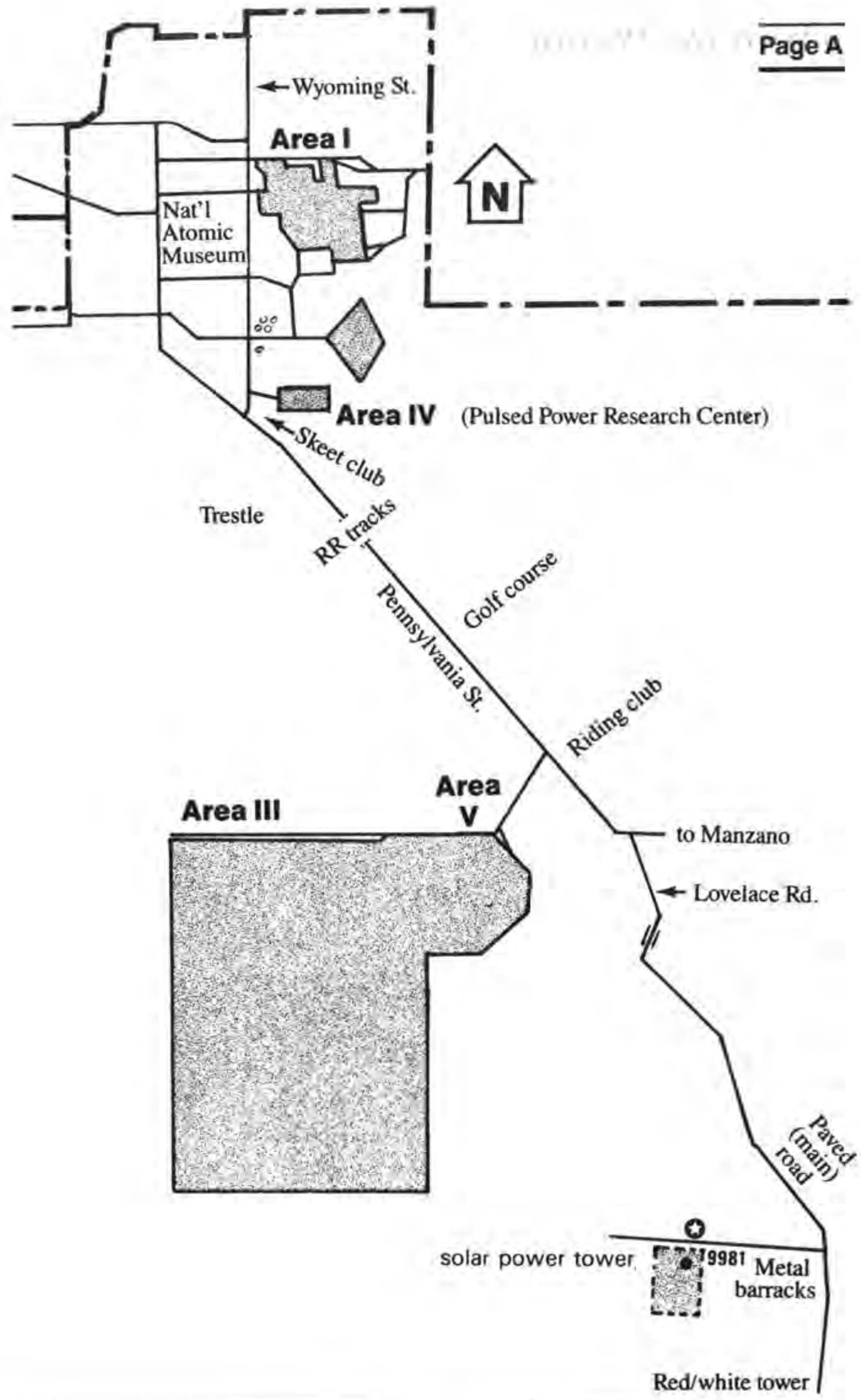
In Area III: gate C-1, from 9 a.m. to 4 p.m.

In Area IV: gate E-1, from 9 a.m. to 4 p.m.

In Area V: gate C-5, from 9 a.m. to 4 p.m.

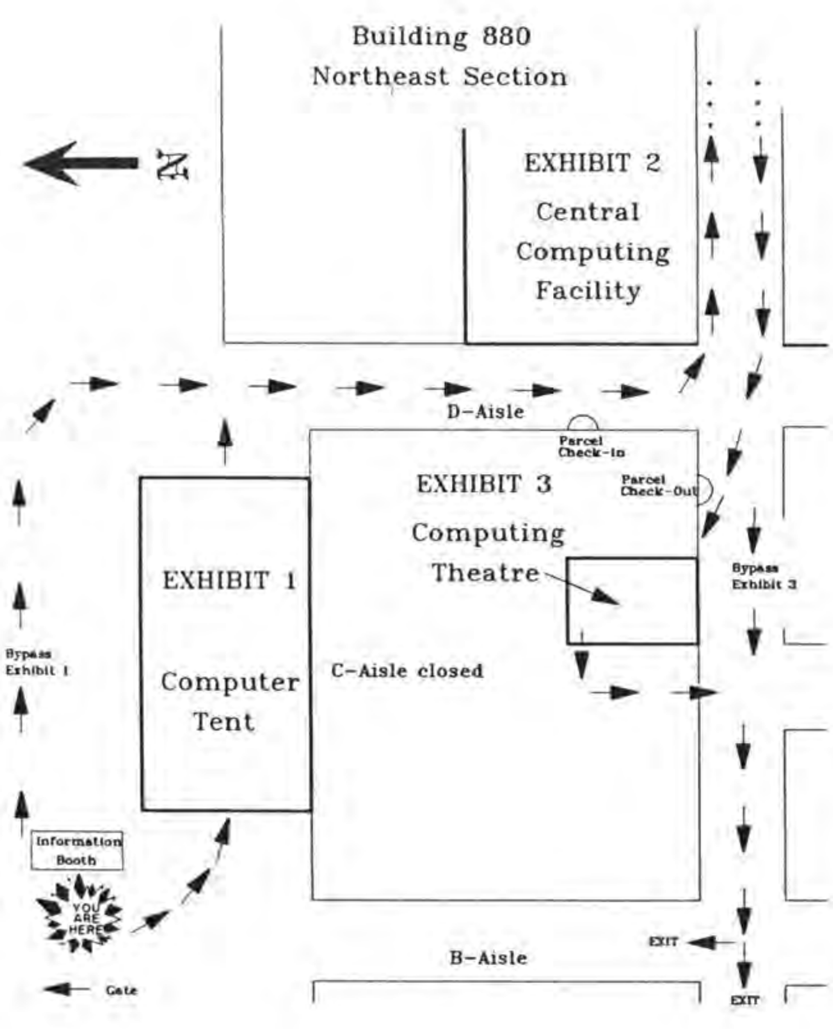
Mardix booths will not be open on Family Day.

(Continued on Page C)



Popcorn, Printouts, T-Shirts

Computer Exhibits in Area I



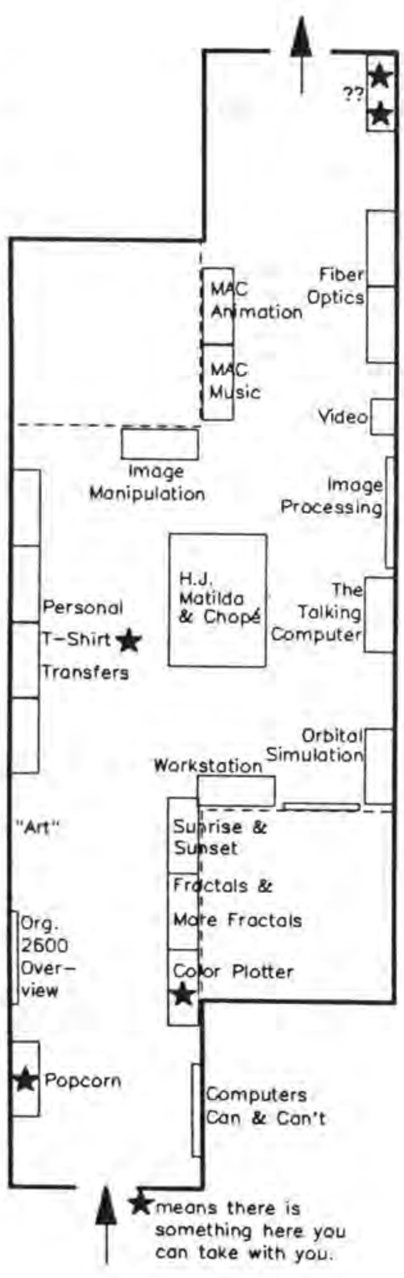


Exhibit One

Computer Tent

Just west of Bldg. 880 will be a computer tent, with Org. 2600's H.J., Matilda, and Chopé at center stage. Handouts (see close-up map on left) include popcorn, T-shirts, color plotter printouts, and a few surprises as well.

Exhibit Two

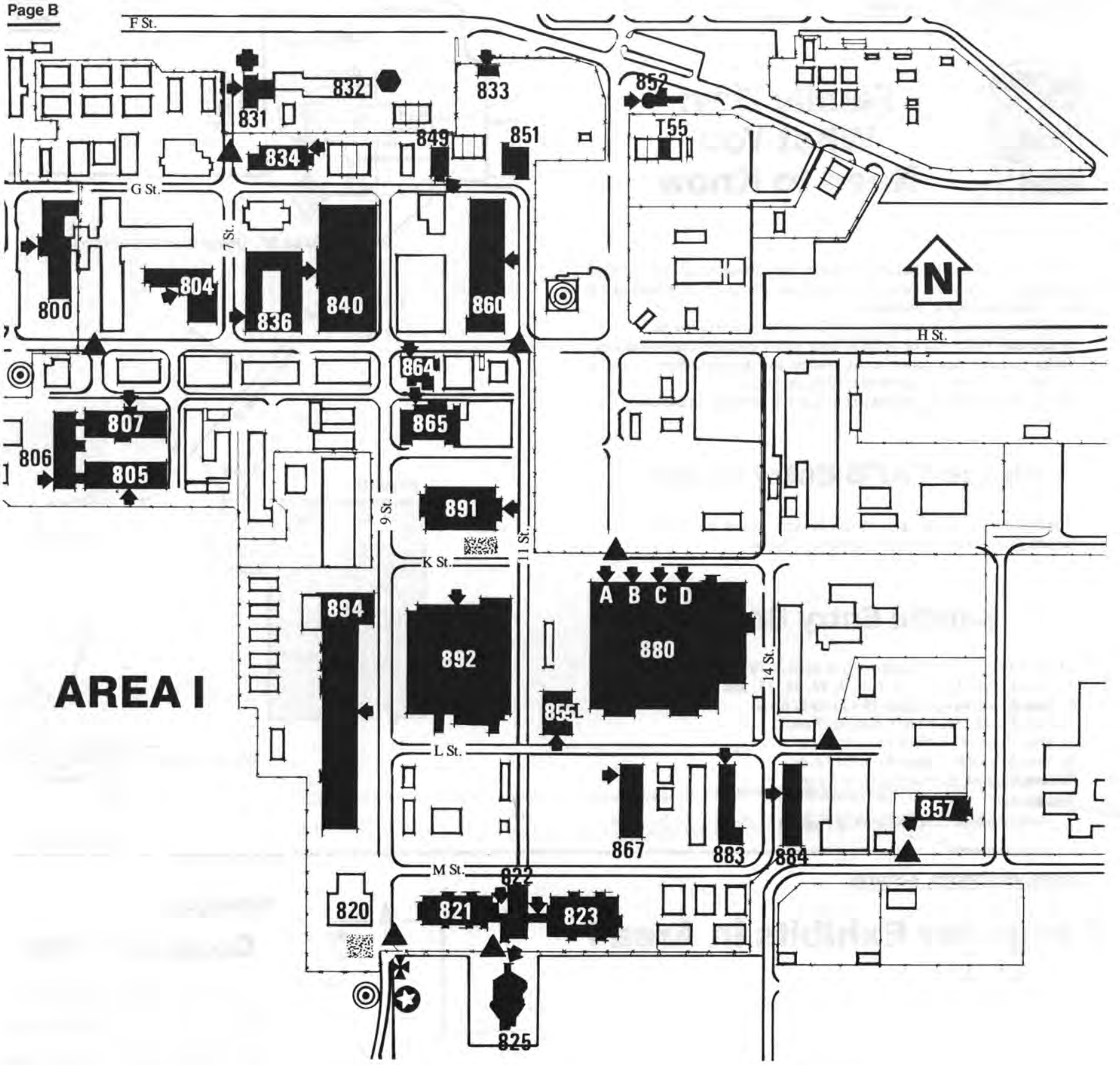
Central Computing Facility

A tour of the Computing Annex (map on far left) centers on the large-scale computers that serve Sandia's heavy-duty computing needs in scientific and administrative work. Staff members will be on hand to answer questions.

Exhibit Three

Computing Theatre

The 20-minute program of computer-produced videos that can be viewed with 3-D glasses include Martian Magnolia, Hot Air, Computer Animation, When Mandrills Ruled, and 3-D Images.



Exhibits In Area I

BLDG.	ROOM	EXHIBIT OR DEMONSTRATION
800	Lobby	Displays of unusual products and services procured by 3700
800	Lobby	Statistical information on 3700's use of the SNL budget
800		PC Software Demos
802	104	Computer Graphics Video Show, Panaboard used for Budgeting
802	Lobby	Weapon Component Development
802	Lobby	Kids View Exhibit
804	10/150	Tech Library-Data Retrieval Systems-Tech Art Display
805	118	Scanning Auger Microprobe Demo
805	123	Microstructure of Welds
805	124	Scanning Electron Microscopy of Integrated Circuits
805	202	Rigid Polyurethane Foam Demo
805	222	Gleeble Test Demo
805	306	Atomic Emission Spectroscopy
805	306	Display of Chemical Analysis Procedures
805	308	Emission Spectrograph
805	312B	Separations of Chromatography
806	159/166	VAX-806 Computer Display
807	2019	Acceleration Sensing Switches
807	2055	Mechanism Analysis
820	Outside	SST Tractor
821		Videotape (Aqueous Foam)
821	1011	"See in the Dark" infrared
821	2203	Video Motion Detection
821	3116	Airborn Intruder Threat
821	3119	Safeguards Alarm Display
821	Outside	Teleoperated and Autonomous Vehicle Display
822		Human-Computer Interfaces
822	ExArea	Liquid Metal Thermal Electric Converter
822	ExArea	Strategic Petroleum Reserve - Narrated Slide Presentation
822	A&B	Hovering Observation Vehicle Display
822	A&B	Intrusion Sensors
822	A&B	Personnel Identity Verifiers
822 & 823	Lobby	Sandia Secretaries "Then and Now"
823	4071A	WIPP Site: Video Tape Program
823	ExArea	Oil from Coal Liquefaction
823	Ex Area	Research for the US Nuclear Regulatory Commission
823	4th Flr	Interactive Graphic System to Demo Repository System Decisions
825		Technology Transfer Center - New Sandia Film - 1 screen
831		First Aid, Blood Pr., Tours, TLC Show and Tell and Lean % Analysis
833		Photovoltaic Advanced System Test Facility
834		Physical Electronics
836	Atrium	Nuclear Weapons Display, B61-7 Bomb, Sea/Air Launched Cruise Missile; Evolution of Trident AF & F Systems; Earth Penetrator; Sea Lance Depth Bomb
836	104A	Test Film
836	208	Engineering Analysis (Computers)
840		Main Machine Shop
849	1, 3 & 4	Geomechanics Instrumentation
851		Autonomous vehicles maneuvering under self control
851		Gantry Robot Fetching and Returning Ball to Thrower
852		Continuous showing of New Sandia Film - 3 screen
855	102	System Control and Receiving Station
855	103	Tactical Remote Sensors System
857	144	Microelectronics (9:30 - 2:30)
860	109B	Animated display of "Sweetspot, wind-turbine and WBB AF & F; Nodal Analysis using Baseball bat and Tennis racket
860	109J	Mech Resonance and Vibration Testing Demo of Various Waveforms
860	115	Photoelastic Strain, Load Testing and Bolt Tightening Demos
864		Glass Lab
865	East	Fluid and Thermal Science Labs
865		Wind Tunnel
867	N Hall	Test equipment utilized in research for US NRC
880	Aisle D	Computer Annex Walk-Through
880	Mall	General Computing
880	A33	Telemetry Display
880	B47	Satellite System Hardware
880	C11	Computing Videotapes
880	C51	Satellite Systems Test
883	4218	TRUPACT -Hardware display and computer analysis involved with R/D
883	Lab F	WIPP Site: Self-Guided Video Tour
884	So. End	5 million volt particle accelerator
891	3414	Graphics for Cable Design
891	South	Electric Vehicles
892	166/173	Hard Link Safety Switches
892	1017/1019	CAE Engineering Workstations, Interactive Graphics for Design Definition
892	207/216	Interactive Video Facility
894	146	Parachute Lab
T55	1	Robot Manipulator, Computer Vision and Artifical Intelligence

Family Day 86 Special

Sandia's Contributions to Nuclear Defense

Irwin Welber
President

Sandia National Laboratories
Albuquerque New Mexico 87185

Dear Fellow Sandians:

Sandia's primary mission is national security. For 40 years the cornerstone of our nation's security has been the nuclear deterrent. And Sandia's major task has been to craft that deterrent. Energy also plays a vital role in our national security, and Sandia has contributed there as well.

But, in spite of the importance of the nuclear capability and the lead role Sandia has played in developing that capability, we've seldom given employees and others an overview of the major contributions Sandians have made to each leg of the nuclear defense triad -- ground-, air-, and sea-based.

Why have we not seen fit to share such knowledge, knowledge that puts into perspective the overwhelming importance of the work done here in protecting the societies that we and our allies hold dear?

One answer is classification. True, we must carefully protect information that could put our deterrent capability at risk, but the articles in this issue have been reviewed carefully by Classification. You will not read anything that is classified.

Another answer is Sandia's traditional reticence. For many years Sandia prided itself on "doing its job, doing it well, and drawing no attention to it." The concept is, perhaps, noble. But it no longer serves us well. The mere word "nuclear" has become taboo for some people, even though it's a nuclear shield that protects them. Today we need a more enlightened employee body, a more enlightened body of decision-makers, and a more enlightened general population.

Which brings us to the third reason -- a new generation of Americans. A generation that was not seasoned by World War II of the early 40s and the Cold War of the early 50s. A generation that has been trained to ask questions. And a generation that is now poised to assume leadership roles at Sandia and elsewhere.

If members of that generation are to perform their vital roles in the nation's defense, they must be more than intelligent and educated. They must be better informed about what we do, how we do it, and -- most important -- why we do it. That is, they must see the interdependent roles and relationships among Sandia tasks. And that means putting these tasks into understandable contexts -- providing the proper perspective, helping all of us to realize that we are part of a community, a community dedicated to the nation's defense.

The primary role of a company newspaper is to nurture that sense of community, to underscore that Sandia is a good place to work, yes -- but more than that: It's a vitally important place to work. And I, for one, am proud to be a part of the Sandia community.

I hope that you and members of your family will take time to read this special issue carefully. I believe you will come away with a better appreciation of Sandia's contributions over four decades to the nation's nuclear defense -- and a deserved pride in a job well done.

Irwin Welber

Safety: No. 1 Priority

Making the Unthinkable Truly Impossible

It happened Jan. 17, 1966. "It" was the mid-air collision — during a refueling operation — between a B-52 carrying four B28 thermonuclear weapons and a KC-135 tanker over Spain.

All four weapons headed toward the earth's surface as the colliding planes broke up. Three landed on the coast near Palomares, and the fourth in the ocean. (It wasn't located until almost two months later at a depth of about 2600 feet. Sandia played a key role in the "sleuth" effort after being requested to help by former Executive Vice President Jack Howard, then Assistant to the Secretary of Defense for Atomic Energy; see LAB NEWS, April 11, 1986, and April 22, 1966.)

Locating the missing bomb was extremely important, but equally significant was the fact that no nuclear detonations occurred as the bombs impacted following the accident. The unthinkable didn't happen.

That's what the nuclear safety business is all about, says Jim Ney, manager of Nuclear Safety Dept. 7230. "Our ultimate goal is to make the unthinkable truly impossible," Jim says. "Safety is the No. 1 priority of the nuclear weapon designer. It is inherent in every decision.

"There can be no second guessing where safety is concerned," he emphasizes. "Safety features are never 'add-ons.' They are part and parcel of the design, and Labs weapon designers go to work on them the day a weapon system hits the drawing board."

Dept. 7230 — charged with continually reviewing and critiquing weapon system safety features throughout a system's design and development — had its beginnings almost two decades ago (in 1968). Jack Howard, upon his return to Sandia from the Washington assignment in June 1966, was the prime mover in establishing the group. Jack — always concerned about nuclear safety, and with memories of Palomares fresh in his mind — felt it was imperative that an independent group, separate and apart from Sandia's weapon designers and developers, be established to ensure that weapon safety would be critically evaluated on a continuing basis. The task of setting up this group, and leading it until his retirement a year ago, fell to Bill Stevens.

Stan Spray (7232), a charter member of Dept. 7230, stresses that predictability is essential in nuclear safety activities. For a nuclear weapon to work, the electrical system and the nuclear system must function together in a predictably reliable fashion; conversely, when detonation is not wanted, these subsystems must behave in a predictably safe way — under both normal conditions and throughout any accident that stresses the weapon. That's where Sandia's safety responsibilities play a key role.

Normal, Abnormal Environments

"We're looking at two different environmental situations," says Stan. "The first — a normal environment — is predictable. We know what to expect, for instance, in terms of temperature extremes or typical stresses that might be encountered in movement and storage.

"The other type of environment — that of an accident, such as the Palomares incident — is a whole new ball game," Stan continues. "An accident — totally unanticipated — creates an abnormal environment that can't be fully characterized in advance because the event is unpredicted. That's why a priority task for Dept. 7230 is the study of accident environments to develop a better understanding of just what might occur. We look at things that could happen throughout a given accident scenario — for instance, an impact followed by a fire followed by a non-nuclear explosion. The idea is to come up with ways to ensure that a weapon's nuclear system, regardless of the stress it encounters, does not receive initiating signals except when intended."

The B-52/KC-135 accident over Spain illustrates this point. The unintended did not happen. Scattering of plutonium occurred when two of the three weapons that hit land broke into fragments. But there was no nuclear detonation.

Safety considerations were at the forefront of nuclear weapon design back then (in 1966) just as they are now, says Jim Ney, "and every succeeding system is safer because of technology improvements and increased understanding. Engineered features are 'designed in' — strictly for safety — to ensure that

(Continued on Page Two)

IRWIN WELBER (1)

We're Proud What you're holding at the moment may well be the most significant special publication ever specially published. Essentially, it's a series of stories about defense through deterrence and Sandia's vital role in that effort. You'll find stories about:

- Reliability. That is, effectiveness, the certainty that weapons will work if needed, in any environment, under any circumstance.
- Versatility/miniaturization. That's what makes possible the major trend of nuclear weapons -- smaller weapons and smaller yields but with pinpoint delivery.
- Command/control. Allows weapons to be stored throughout the Free World without the fear that they could be used against us.
- Safety. These features allow us to store, monitor, and transport a weapon without the fear that it could operate accidentally.
- Long life/low maintenance. Such features make weapons economical and always ready, even after years in storage.
- Special features. Such Sandia developments as the laydown weapon, maneuverability, and terrain recognition have changed, and will change, the nature of the nuclear weapon.

We know that we have not covered every aspect, or even every important aspect, in summarizing Sandia's contributions to weapon systems in the past four decades. For example, we have not covered the extensive weapon testing program; the reason is that we have covered that aspect of reliability and design many times in the past.

Today, we're proud to focus on those lesser-known creative achievements that make our nuclear deterrent an effective defense of our nation.

* * *

We Couldn't Have Done It Alone I thank the dozens of sources and reviewers (especially those in Classification) who helped us with this issue. I thank the writers (Nigel Hey, Rod Geer, Ken Frazier, and Larry Perrine of the Public Information Division and Phyllis Wilson of the LAB NEWS). I thank Charlie Winter, who, as our most highly esteemed LAB NEWS reviewer, again provided the critical eye needed to make our work effective. I thank my boss, Jim Mitchell, who provided the guidance, insights, and motivation to bring the project home at last. I thank President Welber for his strong support of the project and for the inspiring letter on its significance. And, although we could not name each of the contributors to the weapons program, I thank the thousands of current and former Sandians, named and unnamed, without whose efforts there would have been no story to tell.

* * *

Finally, and with High Esteem I dedicate this issue of LAB NEWS to retiring EVP Tom Cook. You have devoted a distinguished career to our nation's defense. We'll miss you, but we'll carry on in your footsteps, TBC.

•Bruce Hawkinson

DENTS, BUT NO DETONATION. Stan Spray (7232), remembers well the collision between a B-52 and a KC-135 over Spain in 1966, and the result: Four B28s dropped from the sky. This one — on display at the National Atomic Museum — was one of three that hit the coast near Palomares (one landed in the Atlantic). None of the four weapons detonated. A priority task of Nuclear Safety Dept. 7230 is the study of accident environments, says Stan, because occurrences such as the Palomares incident create abnormal — and unanticipated — environments in which weapons must not detonate.

Continued from Page One

Safety

weapons have predictable behavior regardless of the sequence or severity of an accident."

As Executive Vice President Tom Cook puts it: "Sandia has always made safety the top priority. We start any project with safety the uppermost thing in the design of any new system. And we have really changed that technology in a very impressive way from what it was in the early 50s.

The Most Serious Design Consideration

"That's not to say weapons weren't safe then," Tom continues. "They were safe. It just turns out that, just like in many things, we've learned how to have more confidence that they're safe. And we've learned design philosophies that ensure they're safe. People always took safety as the most serious design consideration, but we now know how to do it better. Everybody recognizes that people now know how to build better computers than they did 20 years ago. Those same kinds of advances have happened in safety technology."

Sandia's expertise in accident environments is well-known, and the Labs is called upon from time to time to provide after-the-fact consultation, Jim Ney adds. Case in point: When the Army experienced an inadvertent rocket motor firing during a handling operation in January 1985, Jay Grear (7232) was asked to help determine the cause, and Gene Ives (now 8100) was appointed to an Independent Review Team of experts assembled to review the investigation.

When major accidents of any sort occur — even though they don't involve weapons — Sandia pays special attention, in an effort to learn more about the causes and the accident environments. "We've carefully reviewed the Presidential Commission report on the Challenger accident for lessons to be learned," says Orval Jones, Vice President for Defense Programs 5000. "We never take it for granted that we know all there is to know about accidents and their environments."

Strong Links and Weak Links

The so-called strong link/weak link concept typifies the engineered-feature approach to weapon design. Basically, this Sandia concept involves constructing critical components (those needed for arming and firing) of materials that are proved in rigorous tests to be totally unable to withstand abnormal environments such as shock, crushing, or the high temperatures caused by a fire; these components become the weak link. They are placed inside an "exclusion region" protected by, and next to, strong link switches. "You can think of the system's exclusion region as a can — metal, grounded, electrically resistant to penetration — that contains one or more vital

(Continued on Page Three)

Sandia & the Stockpile

As former President George Dacey put it in his 1985 "State of the Labs" message, the nation's goal is "not to enlarge the number in, or the yield of, the stockpile. In fact, total yield is going down, and we are not increasing numbers of weapons in the stockpile in a significant way at all. The builds are primarily to substitute safer weapons that have more control features." Both of these features, safety and command/control, are basic Sandia responsibilities.

And the effort continues. In his 1986 message George noted that "Those trends are still true — the yield is decreasing and the numbers are not increasing. Safety has always been our top priority. It still is, and as the years go by we do a better job of it." At the same time, in command/control, "we're making it more and more difficult for an adversary to use a captured weapon."

ED EHRMAN (2544), one of the principal developers of LAC (lightning arrestor connector), demonstrates internal weapon cabling and a cutaway model of the LAC in this 1978 photo. If lightning zaps a weapon through its external skin connector, the LAC shorts out on the surface of the conducting web and current goes to case ground, thus protecting internal weapon components downstream from damage.

components, such as the nuclear and firing subsystems, inside it,'' Stan Spray explains.

''If the can is exposed to high temperatures [from a fire, for example], those critical components — the weak link — are designed to become nonfunctional long before the strong link switches short out and allow the weak link components to get the electrical signals they must have to operate,'' he continues. ''In a figurative sense, components inside the exclusion area become so much peanut butter long before the strong links fail. So chances for detonation are wiped out.''

A further safety feature is the unique signal generator. Before the weapon system can operate, it must receive a unique signal — one that is not duplicated by any natural phenomenon — to close the strong link switch and allow electrical power to reach the critical components that will permit initiation of the firing sequence. Using a one-of-a-kind signal further ensures that the switch will not operate in an accident environment.

Lightning arrestor connectors, or LACs, installed in weapon systems are another example of designed-in features that combat abnormal environments. A LAC is designed to protect a weapon's electrical system from lightning damage by shunting high currents away from electronic components — again, in a predictable manner. Sandia's work on LACs began some 15 years ago, reports Stan.

In addition to these safeguards against accidental detonation, weapons are prevented from premature detonation caused by careless handling or malicious meddling. The key feature here is the environmental sensing device, or ESD (see the *ESDs* story).

Safety Shared, Not Delegated

Bob Peurifoy, director of SNLA's weapon development organization for a decade and now Vice President for Technical Support 7000, was instrumental in the development and implementation of the features mentioned above. ''Sandia's safety responsibilities span the 'birth-to-death' life cycle of a weapon,'' says Bob. ''From a weapon system's conception through the day it's retired from stockpile, its safety features are given top priority by the designer, developer, and every subsequent custodian.''

Dual-agency responsibility for the U.S. weapons program, establishing a system of checks and balances between civilian and military agencies, was originally established by the Atomic Energy Act of 1946. The concept was reaffirmed in 1985 by a Blue Ribbon Task Group on Nuclear Weapons Program Management when it recommended continuing ''the DoD/DOE dual-agency responsibilities for nuclear weapon safety, security, and control.''

An example of the dual-agency concept in action is the joint DoD/DOE Nuclear Weapons System Safety Group (NWSSG). Dept. 7230 members serve as advisors to DOE representatives on NWSSG, which reviews all safety aspects — operation, design, safety rules, handling, people — of every weapon system.

''Deterrence is the reason for this country's weapon stockpile,'' says Jim Ney. ''For deterrence to work, weapons in stockpile must be reliable and available. If they're not safe, they're not available. And that — in a nutshell — brings home the importance of Sandia's weapon safety work.'' •PW

Command/Control

Weapon Dispersal Without Fear of Unauthorized Use

The awesome power of a nuclear weapon, the primary basis of the Free World's deterrent capability, is matched by the awesome responsibility for ensuring that a nuclear weapon is useless to anyone who does not have specific authority, originating with the President of the United States, to use it.

The ability to meet that responsibility is, to a great extent, based on Sandia technology. Our work in preventing unauthorized use of weapons is what allows them to be dispersed throughout the NATO (North Atlantic Treaty Organization) nations — dispersed without the fear that they could be used by an enemy who overruns a storage depot, a weapon custodian who goes mad, or a terrorist who somehow gains access to a weapon.

Today we take that ''authorized use only'' safe-

(Continued on Page Four)

ESDs

Important in Safety, Ancestors of PALs

An ESD (environmental sensing device) is a component of a nuclear weapon that helps ensure its safety; early ESDs were the ancestors of PALs (permissive action links; see *Command/Control* story).

ESDs are tailored to the type of weapon: bomb, warhead, artillery shell, etc. Each of these undergoes a unique sequence of events that must precede authorized use. An artillery shell must spin; its ESD senses the g-forces typical of that spin. A parachute-retarded bomb must decelerate suddenly; its ESD senses a typical deceleration. A ballistic missile must pass through several acceleration phases as boosters kick in to send the weapon into space; its ESD senses those phases.

If the ESD sees the environment it's looking for, it generates a set of electrical signals (again, a unique waveform pattern over a specified time) that closes a strong link switch and permits the weapon to become armed.

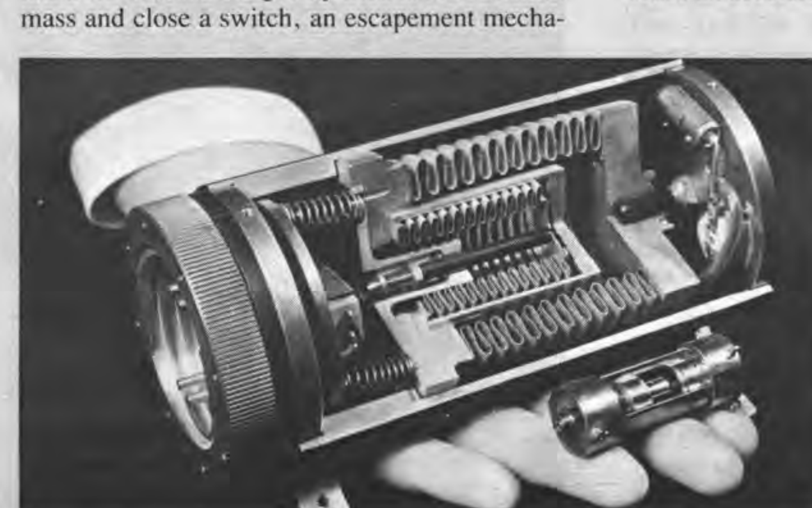
Sandia has developed all the ESDs used in nuclear weapons. An early version was an air-metering device, the 1107 inertial switch. It had a piston with a tiny hole in its center; given the proper g-load, the piston could move (very slowly, because the air had to pass through the hole to enable the piston to move) from one end of a cylinder to another, thus closing an electrical circuit.

Other ESDs relied on fluid, which could flow from one end of a cylinder to another only under strong g-forces over several seconds. Still others were ''verge-escapement'' devices; these worked like a clock in that, as gravity tried to move a small mass and close a switch, an escapement mechanism allowed the mass to move only gradually, over a specified time, toward the closed position.

A unique development in ESDs involved the rolamite concept. Invented by former Sandian Don Wilkes in 1967, rolamite is a nearly frictionless mechanical device with only four major parts: a frame, two rollers, and a flexible metal band. The ends of the band are attached to the frame in such a way that the band forms an S shape. The rollers are held in the loops of the S. The rollers can move freely along the band with little friction because there is no sliding — the same surface areas of each roller and the band always meet.

For ESD applications, the most important characteristic of rolamite is that the band can be tailored — by tapering the band or making cutouts in it — so that the rollers ''prefer'' one position over another. That is, they will stay in one end of the enclosure until they experience a given g-force level; then they will snap to the other end and allow a circuit to close, thus permitting the weapon to arm.

Future ESDs might be built on the principle of the quartz ''tuning fork'' accelerometer, developed and patented by Dale Koehler (DMTS, 2534; the accelerometer application grew out of work with quartz tuning forks by former Sandian Errol Eer Nisse). In an ESD application, as acceleration induces stresses in two parallel quartz strips, the stress in one is opposite to that in the other. So the frequency shifts are opposite, allowing precise measurement of g-forces. Another advantage is that, unlike older ESDs, the new device can sense an acceleration profile continuously.



SMALLER DEVICE is an 1107 air-metering switch. One of the many environmental sensing devices (ESDs) developed by Sandia, it was used to prevent a weapon from arming unless it had experienced a certain unique trajectory. No longer used in modern weapons, the 1107 replaced the integrating accelerometer behind it.

PAL is a Sandia-developed device that prevents unauthorized use of nuclear weapons. A PALed weapon can be armed only after a multi-digit code is inserted into the PAL device. PAL work grew out of Sandia's work on environmental sensing devices, an effort led by Ken Gillespie (ret.).

Continued from Page Three

Command/Control

guard almost for granted, but in the 50s the feature of nuclear weapons we now know as "command/control" had not been directly addressed. The primary push then was to develop a weapon stockpile big enough, powerful enough, and reliable enough to provide, in the key words of that day, "immediate massive retaliation" against any enemy foolhardy enough to use nuclear weapons.

The earliest nuclear weapons had been inherently "safe" because critical components were not assembled until shortly before the weapon was to be used. (The Mk 17 bomb accidentally dropped from a B-36 near KAFB in 1957 could not detonate because its nuclear assembly was not in place.)

Later, however, Sandia had helped to push the concept of a pre-assembled "ready-to-go" weapon, an early version of the "wooden bomb" idea (see *Wooden Bomb* story). The push was successful. The stockpile was changing.

And there was another consideration: The U.S. now had nuclear weapons stored in Europe, that is, in several other countries that were members of NATO. It's true that those weapons contained safety devices that would prevent their *accidental* use, the most sophisticated safety devices then possible (see *Safety* story).

But what about the deliberate use of a weapon that could result if an enemy gained access to the depot containing it? And what about the possibility, remote though it may be, of a deranged guardian of a weapon deciding to use it? (Today, of course, we'd also ask the question, "And what if a terrorist group were able to seize a weapon and hold a city hostage?")

PAL: Son of ESD

That's one side of the story leading to command/control. The other is that Sandia had developed, starting in 1958, the precursor to what was then (and what still is now) one of the primary use-control devices: the PAL, or permissive action link.

That development was more coincidental than calculated. The PAL's remote ancestor was briefly known as a handling safety device, or HSD, then as an environmental sensing device, or ESD. And its function wasn't command/control, as such. Its function was to prevent accidental detonation. This was done by building into each nuclear weapon a device that, in effect, allowed it to say, "I cannot be armed unless I have seen the unique environment that I would see in the use for which I was designed." That meant that a weapon could not be armed unless it had experienced a characteristic set of physical conditions — an acceleration of 4 g's for three seconds, say, for a missile warhead. And a bomb could not be armed unless it had experienced so many seconds of free fall (more seconds, obviously, than it would see if it fell out of a truck).

And so on — for all the nuclear weapon types but one. That one, the atomic demolition munition (ADM), did not have *any* unique "trajectory," or set of characteristics; it would simply be carried to a bridge, say, attached to a girder, armed, and detonated by a timer.

So, as Gus Simmons, manager of Applied Mathematics Dept. 1640, says, "We developed an 'ersatz environment' for the ADM. In essence, we gave it a unique set of preconditions that it had to see — a combination lock — before it would enable. Unless the conditions were met — the proper code dialed in — it wouldn't work."

And that combination lock, which gave the ADM its version of an ESD, was, in a sense, the first PAL, though it didn't have that title yet. (It should be noted that the PAL/ESD approach was accompanied by pressure from the director of Lawrence Livermore Laboratory on Sandia President James McRae for Sandia to build into all nuclear weapons a "golden key," a sort of war/peace switch that would interrupt a primary electrical circuit within a weapon and prevent it from being usable unless the nation were indeed at war.)

A Bit of History

Back to command/control: Two events occurred in the fall of 1960. One was a visit to the Pentagon by Jack Howard, Director of Systems Development, and John Cody, a department manager in the Components organization. The meeting, organized by the Armed Forces Special Weapons Project and held in the Pentagon basement, served to introduce Sandia's new PAL concept and one sample of hardware to all three branches of the military.

"What we told the assembled colonels was that we had developed a device that could separate the physical possession of a weapon from the ability to use the weapon," Jack recalls. "If, we said, an Army captain had an Honest John, that didn't mean he could use it unless his command echelon had given him that authority.

"At the time, the military's response was basically, 'Well, that's a fine solution — but we don't have any problem that goes with it,' " Jack continues.

But that reaction was about to change, thanks to another set of late-1960 events. First, a crash program at Sandia, from Oct. 1 to 17, resulted in prototypes of several new combination locks adaptable to several types of weapons. Second, Don Cotter (later an Assistant to the Secretary of Defense for Atomic Energy and chairman of the Military Liaison Committee) demonstrated those locks, on Oct. 27-28, to a subcommittee formed by the Joint Committee on Atomic Energy, chaired by Chet Holifield (a representative from California) and advised by Harold Agnew (later a director of the Los Alamos lab).

And third, that subcommittee visited the nuclear weapon storage sites in Europe in November. The study they later wrote pointed out that the weapons there were under only "nominal custodial control" of the U.S. military — and therefore not in compliance with the 1958 Atomic Energy Act. Something needed to be done to guarantee that those weapons could be used only under the proper authority.

(It was also during November that Howard Stump, now retired, coined the PAL acronym; at first it stood for Prescribed Arming Link, but later became Permissive Action Link.)

By January 1961, Sandia had developed a redesigned PAL, called Category A (or "Cat A"). Later, a Cat B PAL, which could be operated from a cockpit, was developed.

So now there was a usable PAL and a recognized need for it. And, in June 1962, President John Kennedy signed National Security Action Memo 160, which prescribed PALs for all nuclear weapons involved in support of NATO. "That was the 'hunting license' we needed," Jack says. "Sandia developed the first PALs as retrofits for weapons in Europe, and we've been the key player in command/control ever since."

Managing the PAL System

In essence, both early versions of PAL and their descendents are combination locks — feed in the right combination and the weapon is usable. Given the "if we use any nuclear weapons, we'll use them all" concept of the massive retaliation days, it was nearly decided to put the same combination into all weapons, according to Gus Simmons.

But then someone asked, "What if the combination were compromised? We'd have to change all the weapons to a new combination, a massive task." So each group of weapons (by type, usage, location, etc.) got a unique combination.

The basic plan for managing that effort grew out of a long, hot summer meeting in Paris in 1962; Sandians Don Cotter (now in private enterprise) and Leon Smith (now 5300), General Bert Spivy (U.S. Army), and Ryan Page (National Security Agency) worked out what's become known as the PAL Code Management System.

This early code management system translated pairs of phonetically distinctive words into PAL combinations. One of the reasons for deciding to make the cypher a pair of words, rather than numbers or letters, was that words like Alpha, Bravo, Charlie,

(Continued on Page Five)

GUS SIMMONS (1640), a mathematician and cryptographer, recently won DOE's E. O. Lawrence Memorial Award for his work in establishing the field of authentication as "a central element of public key cryptography." Such cryptography plays a vital role in the PAL Code Management System, which ensures that nuclear weapons throughout NATO can be used only with the proper authority.

Continued from Page Four

Command/Control

and so on were consistent with the normal military voice communications procedures.

Shortly after the new PAL Code Management System was put into use, new — and more secure — PAL devices were designed at Sandia. These required more information in the combinations that enabled them. In addition, the number of groupings of weapons had grown longer than anticipated in the initial PAL code management design.

A Serendipitous Happening

Sandia was charged with developing a PAL code management scheme to accommodate the new PAL devices, and that's where cryptographer Gus Simmons became involved with the new program. (Gus had already been responsible for "blackhatting," or counter-design work, of the earlier PAL devices and systems.) "We developed a system in which one cypher would decrypt into different combinations, depending on the weapon," Gus notes. "The cypher contained information that translated into the combination for groups of weapons.

"As it happened — and it was pure serendipity! — the system we devised contained a modest capability for selective unlocking," Gus continues. "At the time, there was no need for a capability to selectively enable parts of the nuclear force — and we didn't anticipate the need in the design. It just happened that there was some such capability in what we came up with.

"That meant we could choose to unlock only a few weapons for a specific, limited use without compromising the cyphers needed to unlock other, unreleased weapons." A "limited use" might mean detonating just one weapon as a show of force, or using a weapon only to repel a crushing tank attack in Europe or to control escalation of a nuclear conflict.

The New PALs

PALs are now in their sixth generation. In contrast to the early versions, Sandia has developed electronic coded switches, which maintain a weapon in an electrically disabled state. We've also played a major role in developing the Multiple-Code Coded Switch, a lock that can respond to several combinations to permit a relatively high level of selective unlocking for tailored response to a threat.

All PALs have recoding and code verification capabilities; all modern PALs can respond to multiple codes.

In addition to PALs, Sandia has developed an "active protection system," which, if it detects unauthorized tampering, initiates penalty responses that prevent unauthorized use of the weapon.

Taken collectively, Sandia's work in command/control has met its goal: It allows us to be confident that we can deter an enemy by deploying nuclear weapons as needed, without fear that they can be used by anyone without proper authorization. •BH

Reliability

Reliability = Credibility = Deterrence

It was 1962. A young Gordon Boettcher (now a DMTS in Special Applications Div. 2565) stretched his imagination. He had a challenge — come up with a new kind of switch for releasing electrical energy stored in the capacitor of a nuclear weapon fireset.

Analysis of an underground test at the AEC's (now DOE's) Nevada Test Site had revealed that radiation produced by the detonation of an enemy's nuclear weapon could trigger any nearby gas-filled switches that were then used in the firesets of U.S. weapons.

An accidental activation of the fireset would mean premature detonation of a nuclear weapon. Yes, that was highly unlikely, but even the possibility meant that the very strict guidelines that define a reliable nuclear weapon could be violated.

Gordon thought first of tinkering with the gas composition in the switch, but that didn't work. He tested other ideas. No success.

Three years later, Gordon met the challenge with production of the first Sprytron, a vacuum tube switch that is radiation hard. Since that time, many thousands of Sprytrons have been made by commercial suppliers for use in nuclear weapons. (Versions have also been made by industry for different applications in low-voltage circuit timers and even in geothermal well-logging tools.)

Gordon's invention, which received a U.S. patent, typifies the major contributions that Sandia engineers and scientists have made to nuclear weapon reliability.

Reliability milestones have continued to accrue through the decades:

- During the 50s Sandia engineers began to regularly improve the ruggedness of weapons, thus increasing their ability to withstand extreme environments. One 50s technique that designers still use involves encapsulation of various sensitive components in organic plastics. That "potting" minimizes the influence of shock and vibration.
- During the 60s the Labs developed the strong link switch, which has become one of the primary safety components. This barrier, which blocks electrical power from reaching a detonator, must be reliable enough that it withstands torturous temperatures, pressures, and voltages and closes only when it receives the proper unique signal (see *Safety* story).
- During the 70s Sandia pioneered the use of Kevlar in parachutes. By replacing nylon with Kevlar, which appeared first in automobile tires, a parachute's strength-to-weight ratio increased 2-1/2 times, making for a more reliable system.

Most Important Sandia Task

Ensuring the reliability, health, and safety of nuclear weapons from their cradles to their graves is probably the most important thing that Sandia does, according to Orval Jones, Vice President of Defense Programs 5000.

"The burden on each weapon to operate reliably is exceptionally great," he says. "After all, if we're going to continue using nuclear weapons as a deterrent, they must be credible. And if they are to be credible, there can be no questions — in our minds or in the minds of our adversaries — about their reliability."

John Crawford, Director of Weapon Development 5100, adds: "Reliability of nuclear weapons has always been extremely high. Our challenge is to maintain reliability in the face of increasingly complex weapon systems. Over the years we've had to incorporate numerous complicated safety and control components with no loss of reliability."

"Because of this increased complexity," says Jack Wiesen, Director of Systems Evaluation 7200, "ensuring a weapon's reliability certainly hasn't become easier. If we wanted to test a 50s-vintage bomb in its use environment that wouldn't be too difficult. But, to properly test a modern weapon, say an 8-inch shell, so that we can build in reliability and then properly assess that reliability, is quite a challenge. It requires a myriad of complex equipment, such as parachute recovery systems for gun-fired test units, spinners, and temperature soakers."

Sandia works to achieve reliability of its nuclear ordnance by careful planning, design, and testing through all phases of weapon development, production, and stockpile life.

Reliability Report Card

The Labs scores its reliability report card through the stockpile evaluation program that Systems Evaluation Directorate 7200 conducts for the DOE.

"In this way," Orval Jones explains, "by randomly sampling weapons, tearing them down, inspecting components, rebuilding them without the nuclear explosive, and testing for overall system function in the laboratory and in the field, we continuously guard against any degradation that could lead to reliability reductions."

There are many differences between the way Sandia looks at reliability and the way reliability engineers who develop new automobiles look at their task.

Sandians must ensure the high reliability of a system that cannot be fully tested and hopefully will never be used, but which must function without a hitch if needed. Reliability engineers at automotive companies aren't required to meet any of those demands. To them, reliability accrues over time. It is simply a matter of actual observation of their product in normal use.

(Continued on Page Six)

TWO SPRYTRONS are held by their inventor, Gordon Boettcher (DMTS, 2565). Used in a weapon to discharge capacitors for detonator firing and to switch pulse-forming networks, Sprytrons are rugged and radiation-tolerant. They replaced gas-filled switches, which underground nuclear tests showed could be triggered by the nearby detonation of an enemy's nuclear weapon.

Continued from Page Five

Reliability

To be called reliable, nuclear weapons must be able to be stored for many years — except for stockpile testing and replacement of limited-life components — and then work perfectly if ever called on.

For each nuclear weapon development program, the DoD provides what it calls functional reliability goals. An example: ". . . the bomb shall produce the design yield at the burst height or time delay selected with a reliability of not less than 'X'."

9999 Times Out of 10,000

Reliability — technically the probability that the weapon will work as designed — is stated as a number slightly less than 1. Only something that has perfect reliability — it could never fail — is assessed at 1. All weapon subsystems and components also have a stated reliability. These numerical values are based on test data from components, production, and stockpile sampling. For instance, the reliability of Boettcher's Sprytron, which has been improved over the years, is assessed at 0.9999. This means that, based on a myriad of tests, it can be expected to perform perfectly at least 9999 times out of 10,000 tries.

Engineers calculate the reliability of an entire system by using a complex mathematical model that relates system performance to component performance. "For example," explains Dick Prairie, manager of Reliability Dept. 7220, "a system would have an assessed reliability of 0.9 if each of its 10 major components has an assessed reliability of 0.99 and if each of those components must operate."

Typical weapon systems contain 10-15 major components — a radar or a timer, for example. Each major component typically has several hundred electronic parts.

Despite this technical complexity, the DoD requires that stockpiled weapons have "high 9s" assessed reliabilities.

DoD specs also add storage goals: ". . . the weapon shall be ready for immediate deployment without degradation below safety or reliability limits for a period of 'X' years."

Many at Sandia list the wooden bomb concept as the Labs' earliest reliability gold star (see *Wooden Bomb* story). A truly wooden bomb — not yet in the stockpile, but likely to appear someday — would require neither maintenance nor monitoring during its entire stockpile life. The first weapons to enter the stockpile with many wooden bomb traits were the mid-50s' Mk 15/28 family.

"Early weapons were maintenance headaches because they required almost constant field maintenance and monitoring in order to keep reliability at DoD specs," says George Merren, supervisor of Components & Systems Reliability Div. 7222.

Decade-long Effort

John Crawford is one of those who believe that the technology for the true wooden bomb is arriving. He lists advances made over the years in limited-life components as a vital contributor to keeping reliability at the required DoD levels for ever-longer periods. And he cites the increasing intervals that now elapse between the need to change out limited-life components.

"This has been a decade-long, laboratory-wide effort that required materials and physics studies, advances in simulation techniques, molecular physics calculations, and a battery of experiments," John says. As things turned out, the phenomenology and physics of extending the lifetimes of many of these limited-life components were very tightly coupled.

Another major contributor to reliability has been the advent of components that are more forgiving when taken to, or even beyond, their design limits.

A prime example is the thermal battery. Unlike a conventional automobile battery, which contains a liquid electrolyte, a thermal battery has a solid electrolyte. It loses virtually no capacity during years of storage, a feature necessary for long stockpile life. When electrical power is needed from a thermal battery — typically to power a weapon's electronics — a pyrotechnic train ignites, melting the solid electrolyte.

"These batteries went through a definite transition about five or six years ago when we decided to change chemical systems," says Nick Magnani, manager of Power Sources Dept. 2520.

"Their overall reliability, in the final analysis, is about the same as that of the older versions, but the design margin is a lot higher because the new batteries have current-carrying and/or voltage capacities that we don't expect to need," Nick adds. That extra capability, however, can be crucial to reliable operation as evidenced by several recent laboratory development tests of a new weapon. During those occasions more current was required from the thermal batteries than expected. "Our new battery provided it," Nick says. "That would not have been possible with earlier classes of thermal batteries."

The decision to change the chemistry also brought with it an easier-to-build battery and a battery whose performance characteristics are very consistent from batch to batch. Those traits translate into cost savings and improved reliability at the manufac-turing level (see also "Thermal Battery" section of *Stockpile Life* story).

A second major change has also improved thermal batteries during the past several years. Ned Godshall, Exploratory Batteries Div. 2523, developed a new cathode formulation that permits the power sources to give nearly constant voltage throughout their operating lifetimes. The near-constant voltage operation is necessary because many of the electronic components powered by thermal batteries typically operate within a very narrow voltage range.

"Being able to operate within a very narrow voltage range, in turn, has made the task of the electronics designers easier," Nick Magnani says.

Capacitors Another Key

During the past decade, capacitor technology also has taken significant strides that contribute directly to reliability, says Charlie Burks, manager of Weapon Development Dept. 5110. "High-voltage capacitors (the devices whose stored energy is released when Gordon Boettcher's Sprytron switch opens) retain such high reliability scores that they are one of the few major weapon components that are not redundant, meaning there is no need for an alternate capacitor," Charlie says.

A case typical of Sandia's capacitor advances is the work begun in 1973 by Howie Mauldin, now a DMTS in Passive Components Div. 2566. New, and higher, voltage requirements being placed on firesets at that time had placed new burdens on capacitors. Some design changes were needed.

"In practical terms," Howie explains, "the challenge was to develop a means of storing much more energy in a given space while maintaining the required performance reliability.

"That also allowed us to stabilize the performance of capacitors so they could be reliably operated close to their ultimate failure level without a change in performance characteristics." Stable performance in a wide range of operating conditions is vital because capacitors that do not perform uniformly must be severely derated.

Howie's solution — use of a perfluorocarbon liquid to impregnate the capacitor — permits five to ten times more energy storage for a given volume. Although the concept sounds fairly simple, it entails a radical departure from the traditional way of designing a capacitor. Also, Howie says, "It marks the first time that complex physics has been used to

(Continued on Page Seven)

HIGH-VOLTAGE CAPACITORS, which store the electrical energy needed to power a weapon, are extremely reliable devices, thanks to advances in technology made by Sandians such as Howie Mauldin (DMTS, 2566). Here, Howie holds the capacitor he developed, which stores five to ten times more energy per volume than earlier devices; behind him is an exploded view.

Clean Rooms: A Reliability Offspring

Sandia's passion — there's hardly any other word more appropriate — for reliability led to the development in 1961 of an invention that, in this age of microelectronics, has probably had as much effect on reliability worldwide as any single invention. That invention is the laminar airflow clean room developed by Willis Whitfield (ret.).

Willis conceived the idea of having a uniform flow of filtered air sweep steadily through an enclosure, keeping it free of microscopic particles in the air. Such an environment was needed to ensure that miniature weapon components weren't jammed by airborne contaminants. Today, laminar airflow is used throughout the world — in pharmaceutical manufacture, surgery suites, color TV tube assembly, and hundreds of other applications — and is often cited as one of the most significant examples of spinoff from the nuclear weapons program.

With its passion for reliability as strong as ever, Sandia is now building 12,500 square feet of Class 10 clean room in its new Radiation-Hardened Integrated Circuit (RHIC) laboratory, due for occupancy in 1987. Microelectronic weapon components, hardened against nuclear radiation, will be developed in the rooms. Each one will be made more reliable by an environment that will contain fewer than 10 airborne particles that are 0.12 microns or larger per cubic foot — some of the cleanest air anywhere.

Continued from Page Six

Reliability

analyze how a capacitor works, to redesign the basic component."

Besides finding its way into weapons now in the stockpile, this reliable, high-voltage capacitor now attracts the interest of Strategic Defense Initiative researchers.

Microelectronics contributes in several ways to maintaining reliability. Of prime importance is the Labs' pioneering work in research, development, testing, and manufacture of radiation-hardened microelectronics, which designers use extensively in many weapon components.

Sandians in the Center for Radiation-hardened Microelectronics (CRM) and in the labs of the Electronic Subsystems Directorate are working together to make a reality of concepts such as fault tolerance. That is the ability of a weapon to detect a faulty component and to be tolerant of the fault by immediately reconfiguring a subsystem to bypass a suspect part.

Fault tolerance is kin to a new and specialized kind of redundancy that George Merren calls diversification. Although now specific to fuzing — it comes from Trident II Warhead Development Div. 5153 — designers may apply it to other components in the future.

Brute Force Redundancy Gone

"In the early days we relied on a kind of brute force redundancy in our reliability scheme," George recalls. "To reduce the chance of a failure, a bomb would have multiple identical switches, timers, radars and fuzes. We designed the switches to do the same thing, in the same way. If one didn't work another one would.

"With diversification, we don't use two identical items," George explains. "After all, they could both have the same shortcomings. Instead, we're now looking at the wisdom of designing fuzes that operate in different ways, while ultimately performing the same task. We then make the weapon smart enough to choose between fuzing options and activate the type that will optimize the mission."

Work to maintain reliability never ceases. In addition to diversified fuzing, a number of Labs leaders see software verification as one of many major reliability opportunities in years to come.

Jack Wirth, Director of Electronic Subsystems 2300, explains: "We've developed a class of guidance and flight control computers — SANDAC [*SAND*ia Airborne Computer] — that can issue hundreds of thousands of instructions to a missile in a short time span. Those instructions, which come from specially programmed software that goes into SANDAC's memory, must be correct. Therefore we must identify ways of making sure that the software is free of glitches that somehow go undetected until they're brought to the surface by a peculiar circumstance of a particular mission."

One attractive approach to conquering the software design challenge is computer-aided software engineering. The Labs plans its first application of this technique to the development of cryptographic software being designed for use in a command/control subsystem.

As Sandia moves into the 90s, Bob Gregory (Director of Microelectronics 2100 and thereby head of CRM) expects that the modern reliability and quality revolution, clearly manifest in the way Sandia looks at its business and its product, will continue to grow.

More Than the Minimum Standards

He explains: "Our attitude is very important in achieving reliability goals. We're not satisfied with meeting just the minimum standards; we'll continue to work until there's a product that delivers more than what's on the spec sheet."

Jack Wirth expands on that theme: "Sandia's reliability organization, like the safety organization, is completely separate from the project groups. That's important because you don't 'test in' reliability. You design it in. You have to cultivate a whole technology base that draws from experts — in many fields: semiconductors, materials, physics, chemistry, and others — who provide a basic understanding of how things work and why. It's because of that deep understanding, along with our dedicated efforts to understand all of the failure modes that we can achieve and maintain reliability."

Jack Wiesen, whose concerns about ensuring reliability of nuclear weapons span four decades, sums up: "The upshot is that, by use of new or improved technologies, almost obsessive attention to detail, and careful monitoring of the stockpile, we continue to meet all DoD reliability goals for nuclear weapons, even though these weapons have grown vastly more complex through the years and delivery environments much more severe.

"And that accomplishment," he concludes, "plays a major role in guaranteeing our continued safety and freedom." •RG

Stockpile Life

Weapon Longevity Is Engineered In

Imagine this. You were hired in the early 60s to manage a fleet of 1000 brand new cars. Every car in your fleet was delivered with a full gas tank directly to your large fleet-storage building somewhere on the East Coast. Quite a few makes and models of cars make up the fleet. Without starting any of their engines, you rolled all 1000 new cars into the building.

Every five years since, you have entered the building and performed the following minor maintenance on each car: checked the oil, made sure the gas tank was still full, wiped the windshield, and checked the air in the tires.

On a few occasions, you have taken a single car out for a test drive. And you have taken several of the cars completely apart and tested the parts carefully. But you haven't touched the other cars, and their engines have never been started.

Today, when the fleet is 25 years old, your boss calls. "Get all the building doors open," he says. "We're moving the cars. I've got 1000 drivers who will be there in 10 minutes to move the cars to the West Coast."

Under these conditions, how confident are you that more than 950 cars will start, make the cross-country journey without stopping for adjustments or repairs, and still work properly once they get there? Understandably, probably not very confident.

But a similar set of circumstances is faced by those who design, develop, and build the nuclear weapons that serve as our major deterrent to attack. The main difference is that reliabilities approaching 100 percent are necessary.

Primary Design Goals

Since Sandia began operations in the late 1940s, the safety and reliability of nuclear weapons have been primary design goals. Soon after the Labs opened, major efforts were begun to develop weapons that would remain safe and reliable over long periods — in other words, weapons that would have a long stockpile life.

Weapons that have gone into the nation's stockpile in recent years are designed and built to last a long time, with a minimum amount of maintenance. Much of the technology that makes this possible has been developed at Sandia.

During his 33-year career at Sandia, Herman Mauney, now manager of Weapons Evaluation Dept. 7260, has designed and evaluated many of the advances that have added years to the stockpile life of our nuclear arsenal.

Herman notes that the concept of extremely long stockpile life for nuclear weapons really wasn't a primary consideration in the late 40s and well into the 50s. He explains, "In the early years, the primary objective was to deploy a credible stockpile as quickly as possible. The understanding then was that there would be an updating of technology and a turnover in the stockpile in about five to seven years."

Times have definitely changed. Herman says that "normal" stockpile life for many weapons is now 25 years or more — an impressive number that becomes even more so when you consider the complexity of modern weapons. For example, some models of the B61 tactical thermonuclear bomb that was first put into service in the late 60s contain more than 8000 parts.

Herman explains that one of the fundamental purposes of the weapons evaluation program is to anticipate and detect potential problems in new materials and processes early so that stockpile reliability does not suffer. When problems are discovered, his organization works closely with Sandia's design and development organizations to correct the problems.

Bob Peurifoy, Vice President for Technical Support 7000, began his Sandia career in 1952 as an electrical engineer in the systems development organization. Since then, he has worked on many aspects and phases of the weapons program, including ones to prolong stockpile life. During his early Sandia years, he was instrumental in developing the "wooden bomb" concept — a concept strongly related to stockpile life (see *Wooden Bomb* story).

Evolutionary, Not Revolutionary

Bob notes that most stockpile-life advances have resulted not from major, revolutionary developments, but from a great variety of steady evolutionary developments that work together — often in symbiotic relationships. He points to one specific development and broad advances in two general areas that have led the way to longer stockpile life.

The specific development is the thermal battery as a dormant, stable power supply for weapons (see below). Early weapons used bulky and inconvenient lead-acid batteries and other kinds of wet-cell batteries. Today, weapons incorporate a variety of thermally activated batteries for different tasks.

Bob cites numerous advances made by Sandia's materials scientists, chemists, and others to ensure long-term compatibility of the basic materials that go into a weapon — materials that go into the smallest microelectronic components and into the largest mechanical items — as major contributors.

The other general advance that he cites is the ability that has been developed to isolate (seal off) various weapon components, including explosive materials, from one another and from the environment.

Sandia works cooperatively with the two other nuclear weapons laboratories — Los Alamos National Laboratory and Lawrence Livermore National Laboratory — which design the actual nuclear explosives, often referred to as the "physics packages." Sandia designs and tests the non-nuclear parts of weapons

(Continued on Page Eight)

Continued from Page Seven

Stockpile Life

— parts concerned with aerodynamics, weapon safety, security, control, arming, fuzing, and firing systems, and structures.

The details of work in these areas to improve stockpile life over the nearly 40-year history of Sandia could strain the capacity of some good-sized libraries. In a sense, nearly everyone who works on any aspect of weapons at the Labs is involved in stockpile-life improvement.

The limited space here and the fact that many details are classified make it impossible to discuss all major developments, but achievements in the following areas illustrate well the many significant advancements. Most of the achievements are multi-dimensional, contributing not simply to stockpile life, but also to the safety and reliability of weapons.

Thermal Battery

Ask almost any veteran Sandian to name the one class of hardware that contributes most to long stockpile life, and you'll likely hear "thermal battery." The name itself is a bit confusing. Thermal batteries do not produce heat, but are activated by heat. The term "thermally activated battery" describes it better.

Thermal batteries were not invented at Sandia, but they have been refined and adapted to do a variety of tasks since they first replaced wet-cell batteries used in nuclear weapons until the mid-50s. Since then, thermal batteries have been the main type of power source used by Sandia in nuclear weapons.

The thermal battery has an interesting history. It is one of several examples of modern technology that have roots in the German science of the late 30s and early 40s.

Bob Wehrle, supervisor of Battery Development Div. 2522, explains that the German scientist Otto Erb developed the first practical thermal battery cells during World War II. Erb planned to incorporate a thermal battery into a system on the V-2 rocket — the type first used against London in 1944. But the end of the war came before the battery could be used in the V-2 or put to other practical uses.

As were many other German scientists, Erb was interrogated right after the war. British Intelligence gathered information from him, and it was soon conveyed to the U.S. After a series of events and developments, Sandia adopted the thermal battery concept for nuclear weapons.

Bob, who has worked on thermal battery development at Sandia since 1960, says the adoption of thermal batteries for weapons solved some very real problems. From the mid-40s to the mid-50s, the batteries that were used in nuclear bombs were one of three types — lead-acid, nickel-cadmium, or silver-zinc batteries.

THERMAL BATTERIES are composed of poker-chip-like "pelletized cells." Activated by heat, modern thermal batteries contain no liquids and, once packaged in a metal cylinder (upper left), are rugged, long-lived, and reliable.

They all suffered the same basic limitations. They were bulky and contained corrosive liquid electrolytes. (Electrolytes are the substances that conduct electricity when in a molten state or in solution.) These early batteries had to be recharged frequently or the electrolyte had to be carried separately and injected into the battery just before power was needed.

Thermal batteries contain no liquids. They are "one-shot" primary electrochemical devices, nonfunctional at normal ambient temperatures. When power is needed, an external electrical or mechanical signal is relayed to solid, heat-producing chemicals within the battery that produce temperatures in the 550-degree C range. The heat melts the solid electrolyte, and electricity is generated.

Bob says thermal batteries are extremely reliable. For example, an early model of a high-voltage battery (500 volts) was produced in such great numbers that more than 100,000 of them were tested in various sampling programs. The reliability — an impressive 0.99995.

There are other advantages. Thermal batteries have very long shelf lives under normal conditions, and they are very rugged. They can put out a lot of power in a short time, and they are dry and compact.

As with many other stockpile-life improvement efforts at Sandia, progress in thermal battery technology usually came about in a steady, evolutionary fashion. But Bob points to one development that took place in the early 60s that could be labeled revolutionary — the development of the "pelletized cell" concept.

The concept involved mixing the electrolyte and depolarizer together in one batch of powder, placing the mixture in a mechanical press, and applying pressure. The result was something that looks like a poker chip. Another powder, used as the heat source for melting the electrolyte, was pelletized in a similar fashion, and an anode was mechanically combined with the two different types of "chips."

As a result, a thermal battery cell could be made from three pieces instead of the 27 pieces that were formerly required. "To make a battery, we basically

(Continued on Page Nine)

Wooden Bomb

Working Toward the Maintenance-Free Weapon

The oft-heard folksy bit of advice, "If it ain't broke, don't fix it," can be applied to lots of machines and devices, but perhaps applies best to nuclear weapons. The less they need to be handled and maintained, the better — in terms of reliability, safety, and security.

This nuclear weapon concept is often expressed around Sandia by the term "wooden bomb." Coined at the Labs in the mid-1950s, the term describes a design goal that has been largely realized — that a nuclear weapon should require no field maintenance or regular testing. (The goal is now applied to all types of nuclear weapons, not just bombs.)

Bob Peurifoy, Vice President for Technical Support 7000, is one of the Sandia pioneers who developed the wooden bomb concept and planned hardware to implement it. He says the term is meant to imply that a properly designed nuclear weapon should be like an inert log within a forest — able to stay put for years while requiring no attention.

In some respects, the concept is nearly inextricable with that of long stockpile life, but there is a difference. As Bob explains, the term "stockpile life" applies to the absolute useful life of a weapon, something that can be extended by technological advancements (story on *Stockpile Life* gives examples). The wooden bomb concept is the notion that, no matter what the actual lifespan of a weapon, once it goes into the stockpile, it should not have to be tested or serviced to ensure continuing viability.

It isn't feasible yet to absolutely fulfill the wooden bomb concept for nuclear weapons that have extremely long stockpile-life expectancies. Limited maintenance on long-lasting weapons is necessary because some radioactive components decay to less-than-required levels before that long. However, the components can be replaced easily and quickly today by exchanging hardware "in the field," meaning that weapons do not have to be physically removed from the stockpile.

Bob says, "The wooden bomb concept in the 50s suffered primarily from our limited state of knowledge about how to prolong the life of tritium-bearing components, but we have made some dramatic progress since then."

Tritium, a rare hydrogen isotope with a half-life of 12.3 years, is a common radioactive ingredient in most nuclear weapons.

Charles Spencer, a DMTS in Generator Development Div. 2561, says that Sandia's scientific and engineering expertise has paid off handsomely in prolonging the useful life of tritium-bearing components.

Neutron generators, critical components on most nuclear weapons, contain tritium, so they must be replaced periodically. Originally called zippers or initiators, they can be described generally as "triggers." They generate neutrons to start the nuclear reaction.

Even though they must still be replaced in some weapons, Charles notes that tremendous improvements have been made in neutron generator technology. Today, state-of-the-art generators last seven to eight times longer than the ones used in the early 60s.

The wooden bomb concept does not mean that weapons and weapons components are never tested — just that they do not *require* regular field maintenance and component replacement to ensure their reliable functioning, a far cry from the early days when complicated and bulky instrumentation packages and testing systems were required to guarantee the continuing viability of nearly all weapons.

Rather, as part of Sandia's Quality Assurance (QA) program, small random samples of weapons and components are pulled from the stockpile and from contractor production facilities. The weapons and components are then subjected to stringent testing in Sandia facilities; in some cases, the testing includes complete disassembly and detailed analyses of components. The Labs also cooperates in similar QA programs with the other weapons labs, the military, and DOE.

There are several Sandians who helped nurture and guide the infant "wooden bomb" concept during its early Sandia years. The group includes (but isn't limited to) Bob Peurifoy, Eaton Draper, Bob Henderson, and Lee Hollingsworth. Draper is deceased; Henderson and Hollingsworth are both retired.

Bob Peurifoy says the first wooden bomb that went into the nation's stockpile was either the Mark 15 or the Mark 28, depending on how rigorous a definition is used. The first models of these bombs went into the stockpile in the middle to late 50s. Some models of the Mark 28 are still in the stockpile and are expected to remain there for several more years.

Today, the wooden bomb concept is pervasive. Today's stockpile is based on the concept.

Continued from Page Eight

Stockpile Life

just stack these disks together,'' Bob explains.

Modern nuclear weapons use many different models and sizes of thermal batteries. About 20 models, including both pulse-producing and power-producing batteries, are currently in use, ranging in output from about 15 to 500 volts and in size from half a little finger to a fist.

Both pulse and power types are designed to function properly at any time during the stockpile life of the weapon. Once installed in a weapon, the batteries require no maintenance.

Explosive Devices

The many small explosive devices used to perform various tasks in nuclear weapons illustrate stockpile-life advancements well because many of the components that go into the devices incorporate technology developed throughout Sandia.

Explosive Components Dept. 2510 has the responsibility for designing and developing explosive devices. Jere Harlan, supervisor of Explosive Subsystems Div. 2512 and a 22-year Sandia employee, says that the number of small explosive devices varies from weapon to weapon, but somewhere around 10 could be considered typical.

Jere explains that, in some cases, his division takes on jobs that could also be done by electrical or mechanical devices, but explosive devices are used because they are a very efficient and safe way of getting certain jobs done. The explosive materials used in the devices are relatively inert and insensitive, but they also contain a lot of energy for their size — in other words, a small package can be designed to do a lot of work in a hurry.

Among other functions, explosive devices are used in weapons to actuate thermal batteries and neutron generators, automatically disable weapons if unauthorized tampering is detected, actuate valves, close switches on firing sets, impart a spin to selected types of weapons to make them aerodynamically stable, and deploy parachutes used to slow the descent of bombs.

The explosives used in the devices are one of two types — high explosives, which detonate, and pyrotechnics, which deflagrate (burn). Jere says that advances in the understanding of the basic chemical compatibility of each type with the surrounding materials (stainless steel, for example) have made longer stockpile lives possible.

He points out that related quality-control factors also enter into the determination of actual stockpile life. An explosive could theoretically be entirely compatible with a stainless steel encasing it, but careless processing of the steel could change that.

He also says that material compatibility is becoming an increasingly important factor in stockpile life. ''This is because we are using more exotic materials today — materials that have certain desirable characteristics, but some of which are not as compatible with other materials as ones we used previously,'' he explains.

Laser welding is one specific development that Jere says is helping to make explosive devices last longer. ''Laser welding makes it possible to hermetically seal small components, using very low energy levels that do not cause thermal degradation of the components before they go into a weapon,'' he says. Laser welding also does not introduce contaminants into components, a possibility with traditional welding methods.

With noticeable pride, Jere says that the small explosive devices his division develops are among the most reliable parts of nuclear weapons and that they are almost never limiting factors in stockpile life.

''We also often use these devices in a non-redundant fashion,'' he says. ''In many weapon systems, only one explosive device is incorporated to perform a given task, which is not the usual case with some other types of components. This shows you the extremely high levels of confidence we have in our explosive devices.''

Jere is quick to credit the many other Sandia organizations that make such confidence levels possible, pointing out that much of the basic materials and methods that go into the explosive devices were developed by other organizations.

He acknowledges that explosive-device components, as reliable and long-lasting as they are, can be even better. He is excited about the prospects for one particular technology that is in early development — optical ignition of explosive devices, allowing photons to flow into the devices through a fiber-optic electrical insulator.

He says, ''This means there would not be any electrical inputs to the explosive devices, which would go a long way toward solving the long-standing concern that unwanted exterior electrical energy could enter and damage weapon components, maybe even rendering a weapon useless.''

Jere believes that fiber-optic ignition technology will eventually result in inherently more reliable and safer weapons with longer stockpile lives, and which probably can be produced for considerably less money — a combination difficult for anyone to argue with.

Other Achievements

Achievements in two other areas that have improved safety, reliability, and stockpile life of weapons include:

• *Specialty Glasses and Glass-Ceramics.* These materials seal to selected metals used in nuclear weapons at temperatures that preserve the structural integrity of the metals. The glass and glass-ceramic materials are tailored so their thermal expansions match those of the metals; the materials provide environmental seals and electrical insulation for a variety of components.

Concentrated work on specialty glasses and glass-ceramics began at Sandia in the 70s, led by Bob Eagan, manager of Chemistry and Ceramics Dept. 1840, and Ed Beauchamp, DMTS in Ceramics Development Div. 1845. Now led by Frank Gerstle, Jr., this division is involved in a number of projects to develop improved materials for use in weapon components. The work involves close cooperation with the Glass Formulation Section of Inorganic Process Div. 7471; Donn Stewart is division supervisor.

Noteworthy accomplishments are many; the following are indicative of progress made over the past 10 years.

—S-Glass-Ceramic. This high-strength glass-ceramic is used for pyrotechnic actuators and igniters. Invented by Howard McCollister and Scott Reed, Glass Formulation and Fabrication Section 7471-1.

—CABAL-12. This corrosion-resistant glass is used for lithium ambient-temperature battery headers. Invented by former Sandian Eric Hellstrom, now at the University of Wisconsin.

—CON-2. This phosphate glass is used for sealing to aluminum, copper, and stainless steel. Invented by James Wilder, now supervisor of Ceramic Components Development Div. II 2533.

• *Hydrogen Getter.* Now used extensively in nuclear weapons, the hydrogen getter was first used about a decade ago. The device prevents potentially explosive levels of hydrogen from building up inside a weapon and its components. It was invented by Robert Courtney, Adversary Analysis Div. 7234; Richard Anderson, supervisor of Seabed Programs Div. 6334; and Larry Harrah, Systems Research Dept. 310.

GLASS CERAMIC SEAL in a weapon actuator device provides a high-strength bond to the Inconel shell of the actuator and to the electrical pin feed-throughs. The actuators have survived explosive testing to 150,000 psi. Dept. 1840 and Div. 7471 have been developing new and better seals since the 70s.

Several years ago, Larry worked with Keith Mead, Advanced Mechanical Systems Div. 5163, and Henry Smith, Bendix Corporation, to combine the hydrogen getter into a device that also absorbs moisture. A powder was added to the original formulation to prevent moisture-related oxidation, corrosion, and embrittlement problems that could result from condensation or from moisture possibly introduced from an outside source.

Judging Success

Equally important contributions to stockpile life have been made by many other Sandia organizations and individuals — in Albuquerque and in Livermore. Myriad examples from the fields of solid-state technology, microelectronics, parachute design, basic chemistry and physics, engineering design, and others could be mentioned.

Although tremendous strides have been made, Bob Peurifoy points out that the process does not stop when weapons are deployed: ''In cooperation with the other weapons laboratories and the military, various Sandia quality assurance programs draw random samples from the stockpile on a regular basis, and the components are examined and tested in detail. This is the tool by which we judge remaining stockpile life and determine where further improvements may be needed. Certainly, we don't just stick the weapons in the field and hope for the best.''

Obviously, the technology for prolonging stockpile life will continue to expand. Herman Mauney admits that the pace is generally positive, but that it can also present some real challenges.

''Many materials available today are so new that we don't have enough experience with them to adequately judge their useful life, especially under field conditions,'' Herman says. ''We must be very careful not to rush in and use a new technology just because it appears at first glance to be good. We don't want it to turn around and bite us when we don't expect it.'' •LP

SMALL EXPLOSIVE DEVICES are typified by this explosive motor. On right is a bridgewire explosive; gas produced by its explosion drives the piston (left) five-sixteenths inch in milliseconds, and that action can be used to start timers or operate safe/arm switches. Principal developer Bob Burnett (deceased) posed for this photo in 1979.

Miniaturization, Versatility

Greater Capabilities in Smaller Packages

Anyone who has seen the bulging "Fat Man" atomic bomb of 1945 or the mammoth, 42,000-lb., 24-ft.-long Mark 17 hydrogen bomb of the 50s knows intuitively that nuclear weapons have become smaller through the years. Today a modern submarine-based ICBM (inter-continental ballistic missile) carries neatly tucked into its nose an array of nuclear-tipped MIRVs (Multiple Independently targeted Reentry Vehicles), each capable of striking a different target thousands of miles away.

No doubt about it. Nuclear weapons have become smaller *and* more versatile.

"Miniaturization and flexibility — in the nuclear weapons business, the two go together," says Glen Otey, manager of Advanced Weapon Systems Dept. 5160. Miniaturization, he and other Sandians emphasize, isn't an end in itself. It is a way of increasing a weapon's capabilities.

Advances in both have been enormous. Many factors have contributed, from the microelectronics revolution to clever design and packaging. And Sandia has been involved every step of the way.

"In the early 60s," recalls Gene Ives, now Director of Weapon Development 8100, "Sandia began studying what would be required to bring off MIRVs — what are now called MIRVs — and it turned out that if you used the design approaches extant at that time as well as the technology of that time, you just couldn't get there from here. The sizes of the arming and fuzing systems and the nuclear systems were fairly bulky. They were not terribly well integrated from a packaging standpoint.

"To get to MIRVs there was need to cut considerably the packaging volume — or the penalty for packaging — way down."

Sandia and the two other weapon labs began an advanced development program to examine what it would take to carry MIRVs through. "We weren't asked to do this," Gene emphasizes. "But with our cradle-to-grave responsibility, we said we think this is an important national security issue and we think it would be very worthwhile for the country to know the answer."

The project was successful. "By the middle 60s we had done not only the analysis but had largely built the prototypes of all the parts of the system that would allow you to weaponize a MIRV," he says. "Some of these parts were small radars, small neutron generators, small power supplies, small firing systems. But while small, they didn't give up any operational features, and they also provided levels of nuclear hardness that were unheard of."

MIRVing: It Could Be Done

Gene notes that when, in the mid-60s, "the desire for MIRVs really hit in its fullest" in the form of the Poseidon submarine-based ICBM system as well as the early Minuteman systems, "the three weapons laboratories had done their homework such that they were able to show that indeed it could be done.

"And Sandia was able to say, as a result of that advanced development program, that we think it's feasible and not highly risky to commit to development now. We had built and tested these prototypes of about the size, and with about the features, that would be needed."

Charlie Winter, Director of Management Staff 400, tells a related story: Twenty-five years ago his organization, under the instigation of former Sandia President Monk Schwartz and Don Cotter (then a director), was looking ahead to new nuclear weapons concepts coming up in the distant future, the far horizon. Two groups were formed, with Charlie coming to Albuquerque and Andy Lieber (now 5220) moving to Livermore.

"At Livermore," Charlie recalls, "I had been working on integrated RVs." They were integrated in the sense that warhead and RV would no longer be totally separate, either physically or conceptually. If the two functions could be integrated, weight and volume could be reduced.

The various parameters were examined automatically by computers, though hardly today's kinds. "It was all vacuum tubes, no transistors," Charlie says. "That was a quarter century ago. The world was very different.

"We had done our homework on RVs," he continues, "but we also wanted to talk about integrated RVs. We wanted to interest the military in the advantages.

"One of the challenges became 'How light can we build an RV that contains a significant explosive?' We now pursued this at Sandia with the best technology we could conceive of, for a completely integrated RV."

'Free' Structural Integrity

An integrated RV avoids the redundancy of separate structures. "Earlier, the RV shell had its own structural strength," Charlie explains. "So did the warhead. You really needed the structural strength only once. So for structural integrity, count on the warhead, which has the structural strength almost for free. And put no strength into the RV shell."

The other thing that Sandia did was to make the arming, fuzing, and firing package so small that it could fit forward of the warhead. This arrangement copes with the always-present problem of weight and balance in everything that flies. It puts the center of gravity forward, which means the whole thing can be shorter and therefore lighter.

"We did some other radical things in design," says Charlie. "For instance, we did things like design special thermal batteries that would fit into a nook and cranny of the design." No longer did space have to be left open for a big cube-shaped battery. "We did the same with all the other devices — accelerometers, and so on.

"We miniaturized everything and wound up with phenomenally light components. So light that people wouldn't believe us.

"Monk Schwartz did the spectacular thing," continues Charlie. "He realized that no one would believe us unless we actually built the components." So he issued an edict to carry out the program, under the code name Pebbles, later changed to Halberd. He gave it very high priority.

"So we actually built these things, and could demonstrate to the Air Force and the Navy that the weight estimates we had given them were not pie-in-the-sky wishful thinking, but were based on reality."

The Navy decided to implement the Halberd concept in the Poseidon RV.

"It was a phenomenally light RV," says Charlie. "And it went to stockpile, and it worked fine.

"That was the design that Bob Peurifoy [now VP of 7000] and George Rodgers [ret.] implemented. They deserve the credit for really doing that, on time, to design requirements." That wasn't all. All this was accomplished, says Charlie, "not only within budget, but we turned significant money back to the Navy. We actually underran the costs. And people were just flabbergasted."

Radars: Prime Miniaturization Example

Sophisticated radars are a prime example of how nuclear weapons have been made smaller, lighter, and more capable. (Firesets and neutron generators are two others.) The basic function of the radar is to measure the height of the weapon off the ground. In its simplest form, when the radar detects that the weapon has passed through a preset altitude, it provides a signal that fires the weapon's fireset. But modern weapon radars do considerably more than that. And all the increased capability has come at the same time their size has shrunk dramatically.

"The first radars and their power supplies formed a package about the size of that safe," says Charles Burks, manager of Weapon Development Dept. 5110, pointing to a floor safe filling a corner of his office. "Now we're making radars that are the size of a cassette tape recorder, or even smaller, and putting them into weapons."

The comparisons are not all that simple, however. For one thing, radars for bombs don't necessarily have to be as small as those for missile warheads. For another, earlier weapons had dual, independent radars, so if one malfunctioned the weapon would not be incapacitated. Today's modern weapons get by with one — one that is much more reliable, to be sure.

(Continued on Page Eleven)

FAT MAN of 1945

Continued from Page Ten

Miniaturization

Sandians take justifiable pride in the radar technology developed here. "We've probably led the country in miniaturization of radars," says Richard Jorgenson (5113).

Don Arquette summarizes it this way: "As far as we know, we believe we have designed and are producing the world's smallest, lightest, and most reliable radars.

Solid-State Means Small Radars

How did the dramatic size compression/capability improvement come about? Of course modern electronics made a big difference. The old vacuum tubes not only were very large but used high voltages, which required physical separation of components to avoid electrical arcing.

"As soon as we went to solid state, we could provide basically the same function in a smaller package simply because of the difference in solid-state components," Don says.

He lists three technologies that led to the new miniature radars: large-scale integrated circuits for digital processing, hybrid microcircuits for radiofrequency (RF) circuits, and solid-state devices to implement the RF technology. Hybrid microcircuits, which integrate resistors and conductors on a substrate, are to RF circuits what large-scale integration is to digital circuits.

"The hybrid microcircuit technology that we use was strictly developed in-house between Sandia and Bendix Kansas City," says Don. "As for the integrated circuits, their radiation-hardened version is strictly a Sandia development, from the 2100 organization, the CRM [Center for Radiation-hardened Microelectronics].

"With these two technologies we've been able to shrink from several thousand cubic inches for a radar down to less than approximately 20 cubic inches."

Epitome of Miniaturization

The development by Sandia of radars smaller and lighter than are available anywhere else opened the door to bigger and better things (even if they are actually tinier). For a number of RVs, mostly for the Navy, Sandia has gotten into not only miniaturizing individual components like radars but also putting them into an integrated package that is a self-contained arming, fuzing, and firing (AF&F) system.

"That's probably the epitome of Sandia's efforts in miniaturization," in Don's view. "It takes advantage of all the component efforts and further integrates each one into a single functional package. It optimizes the use of power supplies, the use of radiation-hardening techniques, all sorts of things. You'll find that a miniature radar is one portion of it, but a miniature programmer, a miniature fireset, and miniature safing elements are all part of making it successful.

"I believe most people consider that it was Sandia's efforts in a miniature radar that opened the door for us to do the AF&F systems for RVs in the Navy systems."

The latest version of that AF&F system is indeed a marvel of compactness. For the benefit of a visitor, Bill Nickell (5151) sets it on a corner of the desk in Ron Hartwig's (5155) office. It's hardly bigger than a football standing on end. What we are looking at is the AF&F assembly for the W88/Mark V weapon system to be used on the Trident II submarine's fleet ballistic missiles. It will go into production in 1988.

All the components are shaped to fit the RV's curves. "The previous systems have also been small," says Bill. "The difference here is that we're packaging a lot more capability. Miniaturization allows a significant capability improvement."

Bombs More Versatile Too

Not all improvements in versatility have been on missile-launched warheads and reentry bodies. Bombs have been made more versatile too. The B61 modern thermonuclear bomb, for example, has gone through seven distinct models from 1968 through 1986. Each has more capabilities than its predecessor. Charles Burks summarizes: "It can be delivered from lower altitude at higher speeds, and it has better capability against hard targets, improved use control — thanks to modern PALs — and improved nuclear safety."

(Continued on Page Twelve)

MINIATURIZATION ADVANCES make this complete AF&F (arming, fuzing, and firing) assembly less than six inches across. It is part of the Mk 5 warhead for the Trident II missile.

Computer Revolution

Weapon Capabilities Shaped by Microelectronics

Modern nuclear weapons — in common with virtually all other complex devices in today's high-tech world — have been shaped by the computer revolution brought by microelectronics. Computerization of nuclear weapons has made them more intelligent, versatile, flexible, and capable.

"Microprocessors or advanced electronics have allowed us to build smaller, more cost-effective weapon systems that are definitely more capable than their predecessors," says Bill Childers, supervisor of Advanced Systems Development Div. III 1617. "The advent of microelectronics has allowed us to significantly increase the on-board intelligence in the warhead."

Microprocessors were first put into nuclear weapons in the mid-70s. "Before that," says Bill, "you used hard logic, which was just transistors or low-level gates, small-scale integrated circuits, where you'd have a very large number of chips to do the same sort of job. You didn't have a great deal of flexibility. If you needed to change one of the functions, there was a good chance you would have to go in and rebuild your logic boards. Now you simply make a software change and it's accommodated.

"In old missile systems," he notes, "most of the intelligence resided in the missile. It's very important to develop the kind of electronic interface between a missile and the warhead that allows design flexibility on either side of the interface. The intelligent interfaces provided by microprocessors give us that flexibility."

Microprocessors Have to Be 'Hard'

Microprocessors have also given nuclear weapons a wide range of programmable capabilities. But these small computers are not off-the-shelf items: Microprocessors used in nuclear weapons are special radiation-hardened versions designed by Sandia's Center for Radiation-hardened Microelectronics.

The functions in nuclear weapon systems that are managed by microprocessors include programmers, for controlling the AF&F (arming, fuzing, and firing) system and the interface with the missile; trajectory-sensing signal generators for safety; command and control of a weapon; and (where appropriate) guidance and control.

Programmers are the heart of the controllers used now in nuclear weapons systems. Programmers allow what Bill calls "a fairly robust interface" with the rest of the weapon system and the warhead. They allow flexibility in the optional functions of a weapon system, with relatively low cost and low complexity. Programmers have been reduced in volume (from the old to current designs) by more than an order of magnitude — more than 10 times. That reduction has made possible the added versatility programmers now give the weapons.

Trajectory-sensing signal generators are safety components in a nuclear weapon that are used to determine the trajectory it is going through. Their signals allow the weapon to operate only if the trajectory is in accord with a predetermined pattern. "With microprocessor technology, we're able to do a fairly complex job in this area and still function in a fairly reduced volume," he says. "If the trajectory needs to be changed and you're actually using software to define how we measure trajectory, you only make a software change rather than redesigning equipment."

Command and control of nuclear weapons depends on microprocessor technology. "What you are buying here is significantly increased capability — more flexibility in how you control nuclear weapons," he says. "One of the really nice results of that is an intelligent user-interface."

All these applications are really more of a control function than a computation function. "You're really not overly stressing the warhead microprocessor in terms of throughput," Bill concludes.

There is one application in which the computation function becomes considerable. Sandia is using microprocessors for advanced experiments in guidance and control. The heart of that guidance and control is SANDAC, the *Sandia* Airborne Computer. It's a small, modular, very-high-speed, parallel-processing computer capable of carrying out millions of instructions per second. "What SANDAC gives you is the computing power of a large computer in a very small, very rugged package," notes Bill.

What lies ahead in the computerization of nuclear weapons? "I think the future direction in the microprocessor area is a move to what we call microcontrollers or microcomputers," says Bill. "Rather than taking a microprocessor and its associated peripheral support electronic chips, we're now able to put all the support electronics — plus a certain amount of random access memory and program memory — on one chip. So you have a computer on a chip."

Continued from Page Eleven

Miniaturization

All this without changing the external package. Notes Richard Jorgenson: "Every one of the models maintains the same general characteristics — trajectory, shape, carriage — and that similarity has allowed us to progress in weapon design without having to generate entirely new trajectories and aircraft compatibilities.

"If you took the 7, the newest one, and you took the 0, the oldest one, and put them side by side," he adds, "the casual observer would see nothing different."

Some other versatility/flexibility improvements:

- Laydown bombs, a Sandia invention of the 50s. "The first thing that really improved flexibility was the laydown delivery," says Charles Burks. "That was a vast improvement in the way to deliver a nuclear weapon." Rather than requiring the pilot to climb to a higher altitude just as he approaches the target, making him very vulnerable, laydown allows him to release the bomb at a very low altitude while flying at high velocity. The bombs had to be made very strong to withstand low-angle impacts. What was also needed, then developed: parachute technology, strong parachutes, and fast deployment.
- Viable high-altitude trajectories. These involved use of a spin rocket to enhance the stability and repeatability of the trajectory from a high-altitude drop. A bomb with canted fins rolls. But a bomb can also pitch (rock front to back). If the rolling rate and the pitching frequency get close to each other, the bomb can become unstable. "So you make the bomb spin up to a high spin rate and get it above the critical frequency," says Charles. "And the fins are canted to keep it up there. Then you don't have to worry about roll/pitch coupling."
- Logic-implemented options. The idea here is to avoid burdening pilots or missileers with too many tasks. Otherwise, the risk of mistakes is high. "The way we do it now," says Charlie Winter, "is to give the pilot only one task, to select the option. For example, he just punches one button for laydown delivery. The logic in the weapon sets the other things: the timers, the parachute, and everything else."

What Lies Ahead?

"I think we have gone as far as reasonably makes sense in pressing weight and volume," says Glen Otey. He sees costs as a future priority — keeping them down. And he foresees further attention to "increased capabilities without compromising reliability." What will be the main characteristics of future weapons? "Small, rugged, reliable, and probably smart."

Miniaturization and electronics open the way to making weapons more intelligent. For instance?

"The extreme example," says Charlie Winter, "is a weapon that completely senses its environment. It might, for example, carry with it a map of where it is allowed to go off. It might carry with it a description of the people who are allowed to operate it. It would keep track of what physical environment — temperature, pressure, humidity — it has been exposed to, and figure out whether it exceeded its environmental limits. It would do some self-testing to report back on its state of health."

This sensor concept is now an advanced development project at Sandia.

Another concept Charlie mentions has already been explored as an advanced development project and shown to work. Called Tiger, it keeps the pilot from having to go over the target at all. "He can fly next to the target and deliver the weapon to it," explains Charlie. "Or after he's flown over the target, he can have the weapon circle around and detonate over the target so he doesn't have to come back."

No one wants to see nuclear weapons used — ever. But miniaturization has made them small, light, and versatile to help ensure that — if need be — they could be delivered on target and would work as designed. That's what the sober business of deterrence is all about. •KF

Special Features

Sandia and the Nuclear Deterrent: Extra Dimensions of the 'Can Do' Ethos

Deterrence has many faces. One that might at first glance seem remote from Sandia's central role in nuclear ordnance is weapon delivery. Ensuring that a nuclear weapon gets to a target, should it ever become necessary, has prompted Sandians to answer some tough technical questions through the years. For instance:

How do you protect the crew of an aircraft that has just dropped a nuclear weapon at low altitude?

How do you give a missile enough "brain" to know where it is and the sense to get back on course when necessary?

How do you add more firepower to a one-shot missile system?

These questions are just a few that have challenged Sandia's "can do" engineering philosophy during the past 40 years. In that time period, Sandia has contributed to, and sometimes created, specialized technologies that include such esoteric features as the bomb laydown technique, reentry vehicle maneuverability, earth penetration, and automated terrain recognition.

Before discussing each of these, it's important to note that pursuing these specialized R&D areas means that Sandia has pressed the state of the art to new and higher levels in miniaturization, aerodynamics, sensor hardware, signal processing systems, and specialized computer systems. It's also important to note that the Labs has been able to take on these new challenges without compromising other responsibilities within the nuclear weapon ordnance mission.

Laydown: Soft and Low

"In late summer of 1958, an Air Force fighter, flying fast and low over an abandoned airstrip near Dalhart, Texas, dropped an inert nuclear test weapon of unusual shape and, as it developed, of unusual significance. As the delivery plane swept upward, the spike-tipped experimental 'shape' struck the seven-inch-thick concrete runway and embedded itself like a dart thrown into a cork board. Telemetry indicated that the components within the casing had survived the shock of impact and were ready to trigger the detonators at the preset time after impact."

So started an article by John Hornbeck, Sandia president from 1966 to 1972, published in the April 1967 issue of the *Western Electric Engineer*. As the article pointed out, the idea was to lead to an entirely new class of weapons — the so-called "laydown" bombs that had grown out of the need for low-level weapon delivery.

Since the dark days of World War II, military strategists had been keenly interested in equipping bombers with the ability to fly at increasingly low levels, where they would not be "seen" by radar systems — the logic was that if they were not detected, they could not be shot down.

One of the more obvious problems in delivering nuclear weapons at low levels was the safety of the aircrew and aircraft. Thus the laydown bomb was designed to be "laid down" on a target — relatively softly, with the aid of a parachute, instead of merely being dropped — and its detonation is delayed until the aircraft is a safe distance away. An additional advantage is that the soft landing reduces the risk of damage to the weapon's internal parts.

Randy Maydew, manager of Aerodynamics Dept. 1630, was newly arrived from the National Advisory Committee for Aeronautics (now NASA) when in late 1953 his division supervisor, Bob Brodsky, asked him to look into the feasibility of using parachutes to deliver tactical weapons from 2000 feet at speeds of up to Mach 1.2. Randy was doing aerodynamic stability investigations on the Mark 4 and Mark 6 fission bombs at the time.

Although parachute technology was a completely new subject for him, he started reading up on the subject and produced (in record time, January 1954) a pathfinding report, "Feasibility of Parachutes for Low Level Delivery." The low-level delivery (LLD) program began later that year. Meanwhile, Sandia had started a feasibility program on laydown weapons and later joined Air Force and Navy officials in a Defense Nuclear Agency-convened panel on laydown, called the Tableleg Committee. Phase 3 for the first laydown bomb, the B43, began in November 1956. Tests were held over a short period in Los Lunas and at Salton Sea before being moved to Tonopah Test Range.

"I had the job of proving the feasibility of such a project," recalls Dick Claassen, now Vice President of Livermore Programs 8000, then a division supervisor doing work that he calls "nuts and bolts physics," under Ken Erickson in the Weapons Analysis Dept. "The military had considered the idea previously, but didn't have the information to say that it would work, though Sheldon Dike and Walt Wood [then in Sandia's Weapons Analysis Dept.] had done a systems analysis. It was thought at the time we started that the nylon parachutes would burn up at the deployment speeds that were involved.

"The feasibility project was in three parts," he continues. "The first was to determine whether you could have a retarding device that would work at sea level at Mach 1; this started a large parachute program at Sandia.

"The next question was how one would absorb the remaining kinetic energy once the bomb hit the ground. One idea was a nose spike, which both absorbed energy and stopped tumbling, but later on shock-absorbing aluminum honeycomb came into use, and the bomb itself was made more rugged against this tumbling or slapdown.

"The third element that had to be resolved was to make the [explosive part of the] bomb itself rugged enough to withstand the parachute shock and the actual laydown shock. That task was accomplished by the nuclear labs, Los Alamos and Lawrence Livermore."

Dick recalled that there was enough cynicism about parachute-aided laydown in the early days that Sandia let a contract to a helicopter company to develop a propeller-shaped "rotochute," made of com-

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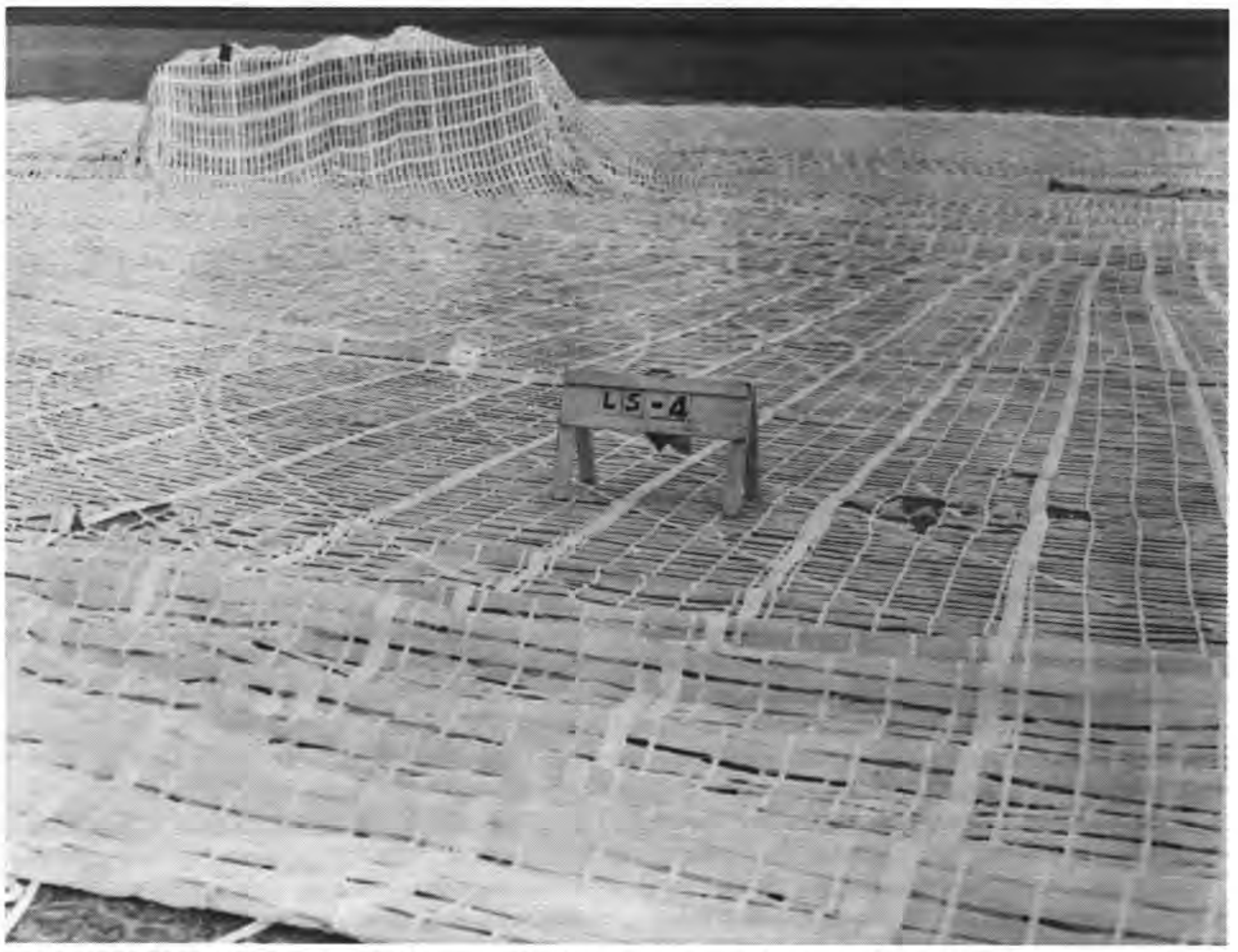

RIBBON PARACHUTES, strips of cloth separated by open space, solve the problem of overloading a parachute with air at high deployment speeds. Ribbon parachutes are a key element of the laydown bomb. Sandia has designed and tested (often, as is the case here, at Tonopah Test Range) all of the parachute systems in the nation's nuclear stockpile.

Continued from Page Twelve

Special Features

posite materials, that would open up as it entered the airstream; a similar device was also developed at Sandia by engineer Carrol Osborne. (Osborne, a classmate of Randy Maydew, left Sandia more than two decades ago.)

The problem of overloading a parachute with air at high speeds was solved with a ribbon parachute, in which each panel is composed of alternating strips of cloth and open space. "If you don't let the air go through and around the materials, what you have is a pressure vessel," explains Carl Peterson of Parachute Systems Div. 1632. "The ribbon parachute intentionally leaks air in order to relieve some of the load so that the rest of the structure is not damaged." The fabric of choice has been Kevlar since the mid-1970s, when this high-strength, low-weight material was used in the 24-ft. chute for the B61-3/4 bombs. Kevlar parachutes weigh as much as a third less than nylon chutes capable of bearing the same load, and can be packed into half or a third as much space.

Sandia designed and tested all the parachute systems in the U.S. nuclear arsenal, drawing upon research performed by German scientists in the 30s to improve the ribbon parachute and to adapt it to special uses. Today, every free-fall nuclear bomb in the U.S. arsenal is equipped with a parachute system.

German technology can be credited with the original invention of the ribbon chute, but it took Sandia to design a suitable test vehicle, a simulated bomb shape equipped with state-of-the-art instrumentation, including high-speed cameras that could look backward and film the parachute as it opened. "We were in close contact with the Air Force experts, and this was the first time they had seen such events in such detail," says Dick. Sandia has worked consistently with the Air Force throughout the development of the laydown concept.

These days a parachute deployed from an aircraft-dropped weapon at, say, Mach 1.2 (about 925 mph at sea level) slows its payload to about 55 mph in about three seconds. However, and not surprisingly, performance varies with the weapon and the delivery velocity and height. A recent example of high-tech parachute design is a system designed for deployment at about Mach 2, a shade under 1400 mph.

The Labs also does pioneering work in the use of clustered parachute designs — it turns out to be more effective for three small parachutes to pull out the big ribbon chute from the casing of a laydown bomb than to use a single canopy. Parachute clusters have been designed for NASA's strap-on Space Shuttle recoverable booster rockets, and for the USAF's F-111 crew ejection pod.

Over the years this work has given Randy Maydew's department a unique set of capabilities that add up to an unofficial center of excellence in parachute design. The group has been called in to do a wide variety of work on high-tech "decelerators," including the drogue system that will be used when NASA's Project Galileo probe enters the atmosphere of Jupiter.

The work is centered in Parachute Systems Div. 1632, under Carl Peterson's supervision, but calls upon the expertise of others within the department (for example wind tunnel testing is done in Don McBride's Experimental Aerodynamics Div. 1634).

Maneuverability: MIRV to SWERVE

Sandia's contribution to what would become a maneuvering capability began with the MIRV (Multiple Independently targeted Reentry Vehicle) program, which dates back to 1961 and to Tom Cook's belief that it was possible "to multiply enemy defense costs significantly" by having a single offensive missile carry a large number of miniaturized reentry vehicles (RVs).

At the time, Nikita Khrushchev was boasting that the USSR's anti-ICBM system was so efficient it could knock flies out of space; thus it followed that the U.S. nuclear deterrent would regain credibility if there were more potential RV "flies" in the Soviet ointment. A new Navy Polaris missile with three Mark 2 RVs was on the drawing board, but Tom was convinced that the U.S. defense community could do better. As a result, Sandia started a major exploratory program named Pebbles, later re-named Halberd (Pebbles was a bit too descriptive for the Classification people). This program investigated the design of RV systems small enough and light enough to mount on an Air Force Minuteman missile in arrays of 10 (at the time, Minuteman carried one RV).

This concept — Halberd was flown in a successful Strypi-launched flight test from Kauai in 1966 — contributed to Tom's selection as a 1971 recipient of the AEC's E. O. Lawrence Memorial Award. The Kauai experiment was the first successful test of a very-small RV and proved a technology that was used in producing the operational Mark 3.

Since then, Sandia's contribution to increased weapon maneuverability has been indirect but vital. The reason is miniaturization, made possible by developments in advanced integrated circuitry, new materials, and smaller electromechanical components (see *Miniaturization* story). Through Halberd, for instance, the weight of the arming, fuzing and firing (AF&F) system was reduced by about two-thirds. The AF&F miniaturization program, accomplished under Bob Peurifoy (7000) and Gene Ives (8100), led to a long and continuing relationship with the Navy in the design of such systems.

Thanks largely to these engineering advances — in which Sandia has played the lead role — the 40-plus years of nuclear weaponry have seen a gradual reduction in the size of bombs and warheads. Beginning in the late 60s, the AEC and DoD were able to develop sophisticated small warheads. This means that smaller, and therefore cheaper, aircraft and missile systems can carry nuclear weapons, and that a larger number of nuclear weapons can be carried by larger, individual aircraft and reentry vehicles. Perhaps more importantly, the submarine became a vastly more potent member of the nation's strategic deterrent; for example, the *Ohio*-class submarine is an awesome mobile missile base that is inherently elusive and hard to target, and which can carry 24 Trident missiles, each armed with several RVs. No part of the nation's nuclear deterrent is more important, or less vulnerable to attack.

MIRVed warheads include those on the RVs developed for the Poseidon (W68), Trident (W76 and W88), Minuteman III (W62 and W78), and MX (W87) missiles. Sandia and other elements of the DOE share responsibility for the warheads contained in these systems, and the armed services are responsible for the launch system and for non-nuclear parts

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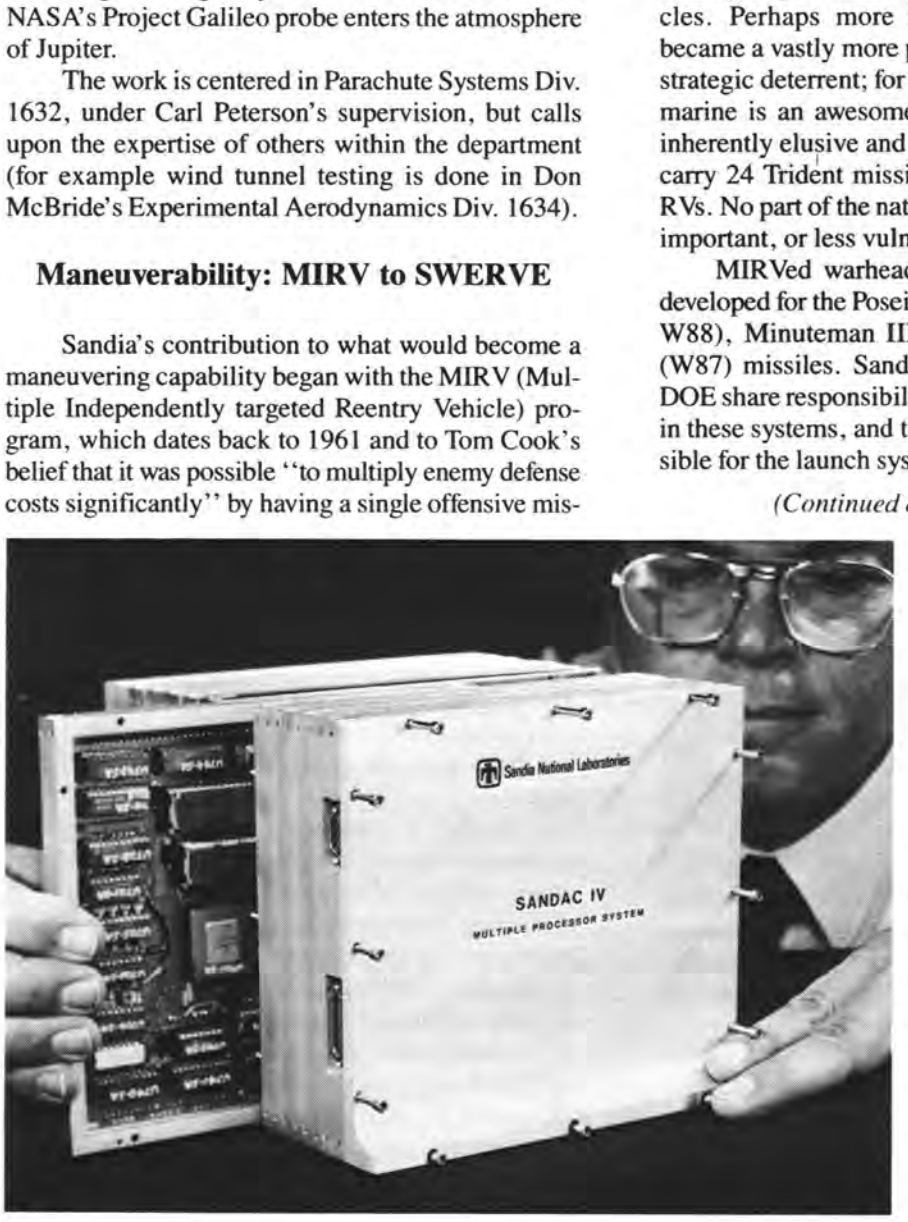


SANDAC IV can fit inside a weapon but has the computational power of a desk-sized computer. The SANDAC embedded computer series (V is an even more powerful version) may someday lead to truly "smart" weapons.

Continued from Page Thirteen

Special Features

of the RV. The missile carries several RVs, each equipped to break out of the normal trajectory and then to follow separate pre-programmed changes in flight path.

Over the last couple of decades, Sandia has gone well beyond MIRVs in investigating various ideas for maneuvering vehicles. One of these was the Extended Range Bomb (ERB), described by Randy Maydew in the *Journal of Aircraft* in 1980. This prototype weapon — two successful flight tests were conducted — was dropped from an aircraft like a bomb, but had a rocket motor and could change its flight path with the aid of canards and a special guidance and control system.

More recently, Sandia has been involved in an exploratory project named the Sandia Winged Energetic Reentry Vehicle Experiment (SWERVE). This program, developed under Don Rigali (1650), utilizes the *SANDia* *A*irborne *C*omputer (SANDAC) and other small, rugged guidance and control components developed in Ed Barsis' Electronic Subsystems Dept. 2330.

Technologies developed originally for maneuvering — and for terrain recognition — have provided valuable spinoffs for application in the new artificial intelligence (AI) robotics work now underway at Sandia. In general, AI robotics technology is centered in Ron Andreas' Exploratory Systems Dept. 1620 and Jim Jacobs' Advanced Systems Dept. 5260.

"We work in the area of maneuverability in order to anticipate the future needs of the services," Tom Cook says. "We're doing some good work, but actual adoption of a Sandia concept of this kind will be in the future, and we would eventually transfer the technology to industry. It's impossible to predict the future — while we didn't make it with the rocket-assisted bomb idea, the laydown bomb concept is already in place."

NEW SCIENCE OF TERRADYNAMICS stemmed from Sandia's studies of earth penetration kinetics. Stabilized by a parachute, this 10-ft.-long projectile was dropped from 2000 feet into soft clay. Deceleration data were transmitted by the antennas protruding from the sides of the projectile. Future weapons may have penetration capabilities, which would minimize radiation contamination of the atmosphere and maximize the mechanical energy transmitted through the earth near a target.

Terrain Recognition

Maneuverability naturally ties in with improvement in guidance and control systems. These in turn benefit from terrain recognition, which provides graphic information that indicates where the moving vehicle is in terms of landmarks; with this information, it "knows" better when and how to maneuver to a corrected flightpath.

Terrain-recognition systems are carried by the ship-, air- and surface- launched cruise missiles, to guide them accurately along complicated low-level routes from launch to target. These are terrain contour-matching (TERCOM) guidance systems, using inertial navigation, automated map-checking, and periodic updating of positional information.

SITAN (Sandia Inertial Terrain-Aided Navigation) systems were independently developed at Sandia, says Ron Andreas. Like TERCOM, they use computer-stored maps and updated inertial navigation data; signals from navigational satellites can be included to cross-check position information. SITAN, proven after TERCOM was selected for cruise missiles, is more accurate than the operational system, and updates its navigational data continuously, rather than periodically. It has not yet been incorporated into operational weapon systems; it has, however, been used in prototypes of video map display systems for use in aircraft and off-the-road land vehicles.

Tiger was a concept for a rocket-boosted version of the B61 standoff bomb, developed under Max Newsom (1610). It incorporated features developed in the ERB project (see above on maneuverability) and had inertial guidance but did not have map-reading capability until SITAN was included as part of the system.

"We have done a lot of solid work in this area that we think will apply to nuclear weapons," comments Dick Claassen.

Penetration: Less Radiation

Although operational earth-penetrating weapons do not yet exist, the concept has several important advantages. For one thing, such weapons minimize radiation contamination of the atmosphere because they bury themselves before detonation. They also transmit large amounts of mechanical energy "sideways" through the earth — enough to squash a reinforced concrete missile silo a reasonable distance away. "It turns out that the coupling effect of the explosion to the ground is very much enhanced if you use an underground explosion," explains Tom Cook. "That's what started us off in penetration work for military applications in the 50s.

"At the time, Dick Claassen had the components part of the research program and I had the effects side," he continues. "Hal Brode, who was then with the Rand Corporation, did a calculation showing that the enhancement of the coupling by burial of nuclear weapon explosions was substantially greater than for conventional explosions. This was a classic study. I took it to Alan Pope [ret.] and asked him to look into it."

Alan, an aerodynamics expert, began Sandia's research in this field in the early 1960s, and in the process became known as the inventor of terradynamics — the study of earth penetration kinetics. The program included the study of information from German researchers who, 20 years earlier, had studied the penetration of artillery rounds into "hard" targets.

Sandia's terradynamics work made it possible to design a free-falling vehicle so that it would penetrate soil and other earth media with maximum efficiency. After studying such variables as weight-to-area ratio, diameter, nose shape and impact velocity, Sandians working under Bill Caudle (ret.) came up with optimum "shapes" that could be used for different purposes. These could carry nuclear or conventional explosives — or instrument packages for measuring the physical characteristics of the media they were designed to penetrate.

Penetrator technology has been adapted for emplacing battlefield seismic sensors and for delivery of conventional explosive charges to breach hard targets such as concrete and steel walls.

EARTH PENETRATOR technologies have a variety of non-weapon applications. Like this one being excavated by terradynamics veteran Wayne Young (1612), penetrators can carry instrumentation that allows researchers to gather data, via telemetry, from earth, ice, even comets.

Wayne Young, project leader in earth penetration studies and a veteran of the early terradynamics days, and a number of his colleagues in Dick Braasch's Advanced Systems Development Div. 1612 are continuing Sandia's pathfinding studies of penetration phenomena — in media ranging from steel to ice — for applications ranging from advanced weapon concepts to probes that could be used to analyze the makeup of comets.

A version of the Army's Pershing II system, carrying the W86 warhead developed with Los Alamos National Lab, was designed as an earth penetrator, but the program was cancelled in 1981 before the system entered production. "At the time it was felt there were not enough potential targets that required the Pershing II penetrator," says Tom. "But as time has gone on we find that the situation is changing."

In a world in which the knowledge of nuclear weapons cannot be erased from the history book of science and technology, the avoidance of nuclear conflict — deterrence — is the most essential of our national priorities. In addition to serving its basic nuclear ordnance role, Sandia has contributed to nuclear deterrence across a wide field of unusual technologies, from parachutes to penetrators. •NH

ENCAPSULATING, or "potting," components allows them to survive severe environments such as earth-impact shock. This unit is part of an earth penetrator, but similar encapsulation techniques have been used since the 50s to minimize the effects of shock and vibration on nuclear weapons.

Sympathy

To Louellen Baldoni (5153) on the death of her father-in-law in Albuquerque, Sept. 17.

To William Tucker (1272) on the death of his mother in Memphis, Tenn., Sept. 28.

To Neita Tucker (153) on the death of her mother-in-law in Memphis, Tenn., Sept. 28.

Attention, UNM Alums

A pair of presidents — Gerald May of UNM and Irwin Welber of Sandia — will host a special reception for Sandians who are UNM alumni. It's special because a proposal for a "Corporate UNM Alumni Chapter" is on the agenda. The reception is set for the ballroom of the Coronado Club on Oct. 14 at 5 p.m. All of Sandia's UNM alums are urged to attend.

Congratulations

To Theresa (3533) and Mike (7815) Carson, a daughter, TreChelle Monique, Sept. 15.

To Bonnie Williams (7865) and Ray Hammond, married in Albuquerque, Sept. 20.

To Anna Marie (7135) and Dennis (3434) Carroll, a daughter, Leanne Margaret, Sept. 24.

UNCLASSIFIED ADVERTISEMENTS • UNCLASSIFIED ADVERTISEMENTS • UNCLASSIFIED ADVERTISEMENTS • UNCLASSIFIED ADVERTISEMENTS

Deadline: Friday noon before week of publication unless changed by holiday. Mail to Div. 3162.

Ad Rules

1. Limit 20 words, including last name and home phone.
2. Include organization and full name with each ad submission.
3. Submit each ad in writing. No phone-ins.
4. Use 8½ by 11-inch paper.
5. Use separate sheet for each ad category.
6. Type or print ads legibly; use only accepted abbreviations.
7. One ad per category per issue.
8. No more than two insertions of same ad.
9. No "For Rent" ads except for employees on temporary assignment.
10. No commercial ads.
11. For active and retired Sandians and DOE employees.
12. Housing listed for sale is available for occupancy without regard to race, creed, color, or national origin.

MISCELLANEOUS

FAMILY DAY SOUVENIRS: Sandia caps, Sandia and TLC T-shirts, $7. So. Highway 14 Village Project, LAB NEWS, Bldg. 814, Rm. 1.

BAND EQUIPMENT, Biamp 1282 mixing console w/road case, EV-SH15 horn-loaded PA cabinets, misc. Shure/EV microphones, stands, cables, etc. Rathbun, 888-3344.

WEIGHT BENCH w/leg lift, 5-position tilt back, never assembled, in unopened carton, $80 new, asking $60. Schkade, 292-5126.

PLATFORM ROCKER, green upholstery, $60; brown vinyl recliner, $65; misc. items. Easton, 256-7717.

HIKING BOOTS, Vibram sole, size 12, $25. Nelson, 881-0148.

FREE DOGHOUSE, good condition, 3500 Holiday NE. Guist, 294-2047.

TABLE, Duncan Phyfe drop-leaf, antique, $70. Smith, 823-9521.

GAMES: Backgammon, $8; Scrabble, $6; Cribbage, $5; Po-Ke-No, $1.50; turkey carving board, metal prong, $6. Smith, 299-7151.

CLARINET, Selmer Paris, wood, collector's item, 17 keys, 7 rings articulated g-sharp, Fork e-flat b-flat, professional model, $450. Lawrence, 268-5479.

TROMBONE, Holton Collegiate, $175. Heid, 892-8608 after 6.

SNOW CHAINS, fit 14-inch wheels, $20. Speakman, 299-8831 after 5.

WATER BED w/heater, king-size, mirrored headboard, $150. Resnick, 292-3825.

TIRES: four, 8.75 x 16.5 Force 4 radials, $140 OBO. Romero, 281-9423 after 7.

ENLARGER, easels, trays, etc., $100; banjo, $25; 24-cup percolator; records; new set of 24 glasses. Watterberg, 299-8517.

LEICA M3-MINT-F2 Summicron 50mm, Elmar 80mm, Hektor 135mm, Leica meter, $750 OBO. Bowland, 256-1861.

CAMPING TRAILER, 16 ft., refrigerator, stove, heater, toilet, double sink, pump, sleeps 6, $1700. Lopez, 265-3296.

BED: frame, box spring, and mattress, $75; 19" Sears color TV, $250. Burkinshaw, 293-7563.

ORGAN, Seeburg Carlyle. Scranton, 299-8801.

GAS DRYER, Norge, older model, $40. Brion, 298-1761.

REDWOOD PATIO FURNITURE, He-Man toys, girl's Health Tex clothes, Nava motorcycle helmet, tank bag, hippo hands, carb stix. Goekler, 296-4162.

COCKTAIL TABLE, carved, solid mahogany wood, $75. Padilla, 898-0379.

AQUARIUMS, two 20-gal. tanks, stand, heaters, etc., $45; helmet, Bell R/T 7-1/8, $15. Russell, 298-0162.

SHARES: Diversified Telephone Portfolio, one-, two-, and three-share certificates, will sell at published price of the day, avoid brokerage fee. Georg, 266-3203.

KING-SIZE MATTRESS with box spring, $75. Reif, 299-2665.

REAR WINDOW FOR '77 Datsun; '60 Ford 1/2-ton pickup parts, $75; Ford/Chev. rims; white toilet; electric boxes and 1/2-HP motor. Padilla, 877-2116.

ANTIQUE BEDROOM SET: 3-piece, cherry wood, 7 ft. wardrobe, headboard, and curved footboard, dresser w/mirror, $800. Baca, 296-8474.

TWIN BED with solid oak headboard, frame, box spring, and mattress, $40. Beeler, 822-9485.

TIRES AND WHEELS, 235/175-15, fit 1/2-ton Ford van or truck, used 20K miles, set of four, $75 OBO. Tarbell, 292-0141.

HAVILAND CHINA, service for 12, complete accessories, $800 OBO. Searls, 296-1543.

AUTOHARP, 15 chords, w/case, $125; antique piano w/bench, both refinished, $650. Coalson, 298-0061.

SEARS CHAIN SAW, case, and tools, $150. Dean, 299-3281.

MATCHING BABY FURNITURE (three pieces): high chair, $15; play pen, $20; swing, $15; car seat, $15; Hoover upright vacuum, $25. Troncoso, 897-1167.

TABLE AND 4 CHAIRS with rollers, $150 OBO; jungle-print curtains, bedspread, and 2 fabric arts, $40. Philipbar, 296-5878.

TEKTRONIX oscilloscope cart, type 500, $10. Moody, 281-3466.

ENLARGER, Beseler 67CP2 with color head, for 35mm and 6x7cm films, $125. Olsen, 281-9138.

REMINGTON 30-06 RIFLE, model 1903, bolt action, Williams open sight, $150. Reed, 821-7445.

COUCH with matching recliner; portable Whirlpool dishwasher with cutting board top. Patton, 898-3524.

CANON SLR 35mm, 80mm, 200mm, $180; 18 Time/Life photography books, $60; maple twin beds (no mattress), $40. Ginn, 883-0004.

POWER LAWN MOWER, Sears, 3-1/2 HP, rear-bag grass catcher, self-powered, $75. Walston, 296-0372.

RUGER MINI-14 RANCH RIFLE w/3-9 variable scope and some accessories, $500; Browning high-power 9mm pistol and accessories, $400. Scranton, 869-6589.

FIREPLACE HEAT EXCHANGER, Sears Best, $75; Smith-Corona correcting electric typewriter, new, $200; electric cooktop, 4 burners & griddle, $20 OBO. Zipperian, 821-2309.

CONN TRUMPET with music stand, $275; boy's bike, Huffy "Pro Thunder" with thorn-proof tires, $35. Benson, 296-4282.

ROLLAWAY bed, sleeps two, $85; kitchen table w/6 chairs, $35. Maestas, 831-4072 after 5:30.

LA-Z-BOY ROCKER/RECLINER, light brown, $350. Smith, 299-6873.

FREE FERTILIZER, composted horse manure, for new lawn preparation or gardens, lots available, you haul. Moore, 345-4030.

COLOR TV, 25" Mitsubishi console w/AM/FM stereo radio, remote control, medium oak cabinet, 3 years old, $650. Petitt, 296-7049.

DINING TABLE, heavy, teak, 60" x 35", w/2 detachable leaves, $650. Lyngen, 292-5027 weekdays.

FIREPLACE SCREEN, 28" x 32", $10; Delco AM/FM radio, all connections marked, $20; bath cabinet and light bar, 46" x 29", $15; 2 cradles for 20" Cabbage Patch dolls, $25/ea. Peters, 293-6356.

PIANO WITH BENCH, Lester spinet, cherry wood, $895. Baczek, 255-3429 days or 268-6366 evenings.

WHIRLPOOL GAS WALL OVEN, 30", never unpacked, $200; mahogany kitchen cabinets, $50; large Sears portable dishwasher, $35. Mozley, 265-2625 or 299-4204.

UTILITY TRAILER, 4' x 6', metal bed, tailgate, fenders, $75. Hole, 255-1444.

TIRE CHAINS, new, fit most medium-size cars, half price. Heames, 293-6550.

FREE PUPPIES, 9 left, assorted colors, medium-size, history available. Bukaty, 345-4691.

GARBAGE DISPOSAL, Insinkerator, new in factory-sealed box, 1/3 HP, Badger I model, $40. Lagasse, 293-0385.

MAYTAG WASHER AND DRYER, almond color, $400/pair; antique buffet, $450; fine china, 45 pieces, $150; recliner, $100. Tomek, 299-0471 leave message.

DISHWASHER, Sears Kenmore, standalone, white, butcher-block top, $75; 11' x 11' light golden brown bound carpet, $15. Burstein, 821-6688.

SKIS, new K2195 with Tyrolia 360 racing bindings; Nordica size 12 boots, poles, used twice, $250 OBO. Foster, 299-6240.

ANTIQUE VICTORIAN SOFA and chair, $600; pair of gold recliners, $150/ both or sell separately. Chavez, 243-4510.

RUGER .22 AUTOMATIC PISTOL, $100; Sunpack 522 automatic professional photographic flash, $100. Montoya, 296-4268.

TRANSPORTATION

TOURING BICYCLE, Bertin 61cm, upgraded, extras include spare components and tools, more than $1100 invested, asking $450 OBO. Rathbun, 888-3344.

'75 HONDA 750cc, 6" over forks, custom seat and exhaust, $850. Pilch, 821-4913.

'84 HONDA ASPENCADE, 22K miles, full radio package, custom pin striping, helmets included, $5500. Brandon, 836-5621.

'75 TOYOTA CELICA, AT, radio, AC, $1750. Ostensen, 296-4227.

'84 HUSQVARNA DIRT BIKE, 250cc, used less than 10 hrs., $1800 OBO. Ulibarri, 877-5320.

'84 TOYOTA TERCEL SR5 station wagon, 4-wheel drive, AC, AM/FM stereo cassette, trailer hitch, low mileage, below retail book. McMurtry, 881-8053.

'79 PORSCHE 924, low mileage, new paint, AC, Blaupunkt stereo, $6500 OBO. King, 873-0154.

'61 INTERNATIONAL B160 TRUCK, 8' x 12' stake bed, 2-spd axle, 12,000 GUW, rebuilt V-304 spare engine. Class, 281-3836.

'67 DODGE 3/4-TON PICKUP, overhead camper, sleeps 4, sink, stove, refrigerator, $1900 for both, will sell separately. Tucker, 831-3660.

'72 VW SUPER BEETLE, AM/FM cassette, $950. Mora, 821-6759 after 6 weekdays.

'77 VW SCIROCCO, needs some work, $1200 OBO. Volk, 256-9214 after 5 weekdays.

'73 PONTIAC STATION WAGON, 6-cyl., AT, $400 OBO. Hill, 299-5272.

'82 YAMAHA VIRAGO 920, tinted windshield, $1000; two '55 Ford 1/2-ton truck bodies, $500/ both. Padilla, 873-1480.

'77 FORD MAVERICK, AT, PS, PB, V8 302, 4-dr., 80K miles, AM/FM cassette, $1100 OBO. Baca, 898-2244.

'78 HONDA STATION WAGON, STD, 75K miles, $500. Reif, 299-2665.

'65 SCOUT 4-WD, 55K miles, $2500. Dean, 299-3281.

'76 DATSUN B-210, radio and tape deck, $950 OBO. Shipley, 298-2433.

'80 MAZDA RX7, 60K miles, 5-spd., AC, $4200 OBO. Kramer, 883-0574.

'70 FORD ECONOLINE VAN, needs work, $600 OBO. Anderson, 888-4993.

'72 MAZDA RX2, 4-dr., 4-spd., AC, $500 OBO. Bradley, 293-9586.

'74 FORD COURIER, engine problems, $350. Otey, 294-1874.

'66 MUSTANG, 289 V-8, 3-spd., AC, new red paint, black interior, restored and maintained, $3500. Tennyson, 292-5844.

'68 LINCOLN CONTINENTAL, forest green, 4-dr. sedan, "suicide" doors, white leather interior. Hill, 292-1438.

'73 MAZDA RX2, 2-dr., 4-spd., stereo, $700 OBO. Stuart, 265-7315.

SAIL BOAT, Sunfish, w/trailer, $1200; sailboard, Tiga Allaround, $400; life vests (7), $15. Ginn, 883-0004.

'61 CHEV. IMPALA, 2-dr., hard top. Keiss, 299-3312.

'70 CHEV. NOVA, 3-spd., 6-cyl., mags, new tires, $750 OBO. Reed, 821-6315 after 6.

'77 BUICK LESABRE, 78K miles, AC, AT, PS, cruise, 4-dr., one owner, $1600. Kinney, 298-5281.

'82 SUBARU GL WAGON, 2-WD, AT, AC, PS, PB, cruise, AM/FM, PW, 48K miles, $3500; Peugeot 10-speed bicycle, $40. Zipperian, 821-2309.

'84 FORD RANGER 4X4, power steering, 5-spd., Explorer package, 24K miles, $6500. Anderson, 883-2746.

'79 CUTLASS SUPREME, AT, AC, PS, PB, AM/FM stereo tape. Randall, 821-0388.

'80 JEEP CJ5, 28K miles, one owner, custom hard top, 6-cyl., 4-spd., $5500 OBO. McCarty, 823-2926 after 5.

'75 CHEV. CAMARO, new paint, $2400 OBO. Baca, 292-4790.

'67 VW BUG, $450. Kaemper, 255-3927.

'73 CHEV. PICKUP, 3/4-ton, PS, PB, AC, AM/FM cassette, 2 gas tanks, camper shell w/padded insert, new transmission, $2000 OBO. Grider, 281-2893.

'73 MGB CONVERTIBLE, rebuilt engine, new top, seats, paint, no rust, custom roll bar, $2100 OBO. Cowgill, 298-1357.

'80 AMC CONCORD, 4-dr., AC, AT, new radials, AM/FM stereo cassette, medium blue inside and outside, hit in front left, not running, $250 OBO. Dubicka, 296-6557.

'60 JEEP CJ5, 4-cyl, F-head engine, 3-spd., self-adjusting 11-in. brakes, full metal top, 50K original miles, tow bar, extras. Alexander, 884-4930.

'83 BUICK LESABRE, loaded, 2-tone paint, new tires, EC, $5495. Stewart, 293-3959.

'78 FORD GRANADA, 37K miles, 4-dr., AC, PS, AM/FM/8-track/cassette adaptor, new tires, battery, shocks, $2000. Laval, 898-9112.

REAL ESTATE

2-BDR. MOBILE HOME, 12' x 60', furnished, washer and dryer. Atencio, 881-6945.

2.5 ACRES mountain land, off South 14, one hour from Albuquerque, trees, water, view. Zawadzkas, 884-8956.

3-BDR. HOME ON 160 ACRES, Estancia Valley, corrals, in permanent pasture, 2105 GPM well w/underground irrigation, $162,000. Hayes, 281-9282.

3-BDR. HOME, on corner near Los Altos, 1100 sq. ft., 1-1/2 baths, garage, sprinklers, $63,500. Sparks, 821-8442.

3-BDR. HOME, near Georgia & Constitution, 1390 sq. ft., Roberson-built, wood floors, solar collector, double-glazed windows, landscaped, $71,500. Louden, 255-3031 or 292-4504.

7.98 ACRES, north side of Heron Lake, private road, locked gate, $6500 per acre. Roehrig, 588-7330.

3-BDR. TOWN HOME, 2 baths, great room, FP, self-cleaning oven, microwave, 2-car garage, patio, large closets, landscaped. Ruminski, 293-3207.

3-BDR. HOME, UNM area, study, den, FP. Blea, 268-5216.

MOBILE HOME, '84 Vogue Fleetwood, lawn landscaped, set up in North Hills Mobile Home Park, $19,900. Reed, 821-7445.

3-BDR. GEODESIC DOME on 2.3 acres south of Edgewood, 2 baths, patio, $79,000. Stout, 281-3108.

THREE LOTS, 2+ acres each, 15 minutes from Kirtland on west side of North 14. Southwick, 281-3782.

3-BDR. HOME, Heritage Hills, 8820 Armistice, 1-3/4 baths, 1700 sq. ft., great room, covered patio, professionally landscaped, $107,500. Martinez, 822-0744.

3-BDR. HOME, near Indian School and San Pedro, new red oak cabinets, beige carpet, roof, and paint, approx. 1100 sq. ft., $65,500. Reinarts, 881-6135.

SEVEN SECLUDED MOUNTAIN ACRES, 217/222 area, wooded, meadows, views, $3800 per acre, R.E.C. or cash. Kelton, 345-3834.

3-BDR. HOME, newly remodeled, 1-3/4 baths, garage, 1500 sq. ft., no qualifying, immediate possession, $72,800. Stanalonis, 298-7903.

3-BDR. HOME, 1-3/4 baths, 2-car garage, ceramic floor tile, 1650 sq. ft., 9 years old, near Lomas and Chelwood, $92,500. Sepulveda, 299-2805.

4-BDR. HOME, 2-1/2 baths, den, 2600 sq. ft., split-level, plus 750 sq. ft. finished basement game room, oversize garage, cul-de-sac lot. DeWerff, 298-1029 evenings and weekends.

2-BDR. MOBILE HOME, Four Hills, 2 baths, double-wide, appliances, 10' x 13' wood shed, yard with view, owner can finance. Ash, 821-7127.

TWO HOMES: Jewett NE, 3-bdr., 1-3/4 baths, double garage, $79,000; Dakota NE, 3-bdr., all-brick Mossman, $89,500. Grube, 884-0853.

WANTED

QUEEN-SIZE WATER BED, prefer accessories but will consider without. Cocain, 836-7127 after 5.

TRADE: would like to trade canning jars for produce. Hill, 299-5272.

1-BDR. HOUSE for medium-size dog. Negin, 266-1983.

CHAIN LINK FENCE, 4 ft. high, with hardware. Fenimore, 298-8052 after 6.

HOME for 3-year-old German Shepherd, female, with papers, will give away to good home, great with kids. Dunkin, 892-8234.

MOTORHOME TO RENT, Dec. 19-20 and again on Jan. 3-4, nonsmoking adults, transportation only, no use of plumbing or kitchen. Caskey, 296-6372.

WORK WANTED

HOUSE-WATCHING, plant or pet care, etc. while you are away, anytime. Lambert, 294-4188 after 5:30.

SHARE-A-RIDE

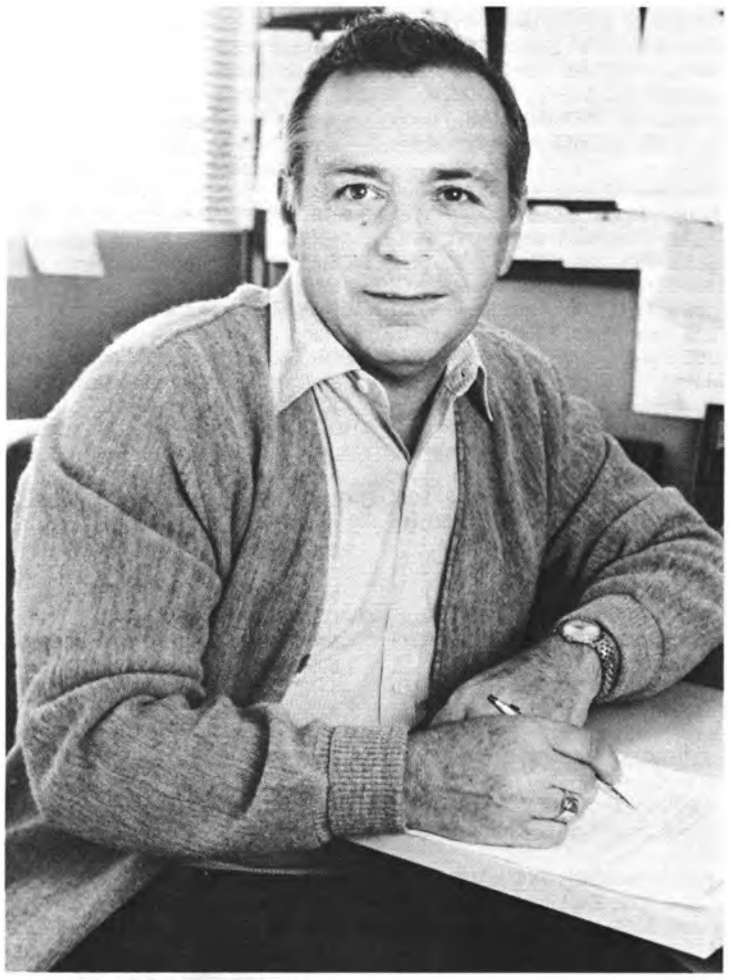
CARPOOL from vicinity of Eubank and Montgomery (Hilton Place) to Medical Gate. Sorrell, 292-0874.

MILEPOSTS

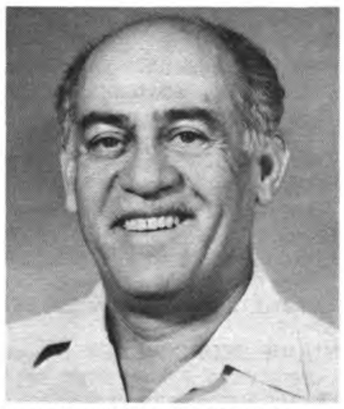
OCTOBER 1986

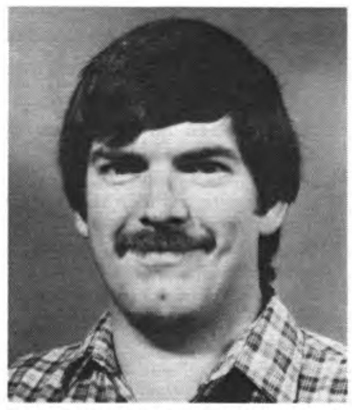

PEGGY POULSEN (3141) 25


DICK JENNINGS (8025) 20


BILL GAMBERALE (7864) 35

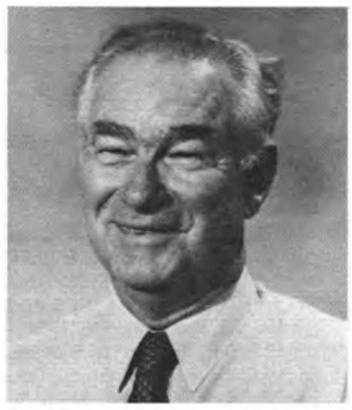

NESTOR PEREA (7815) 15

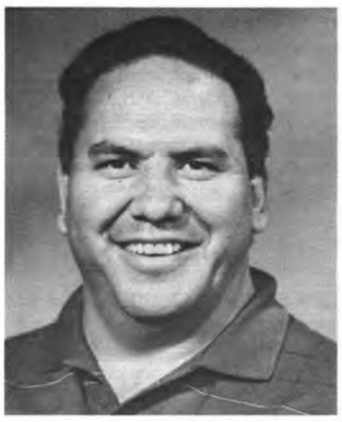

BENITO CHAVEZ (2632) 25


RICHARD STUMP (3312) 10

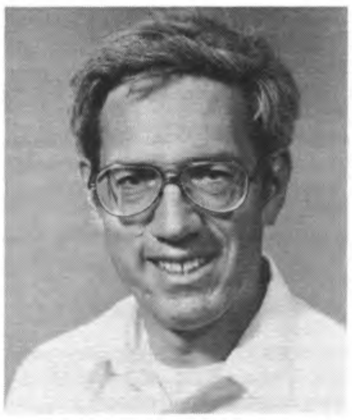

DWIGHT SORIA (8257) 20

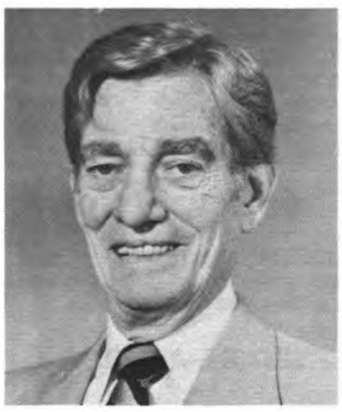

BARBARA STALEY (3522) 10

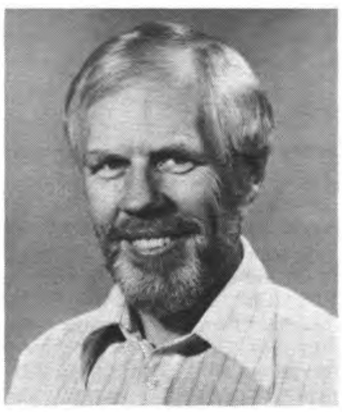

CHARLIE DUVALL (2853) 25

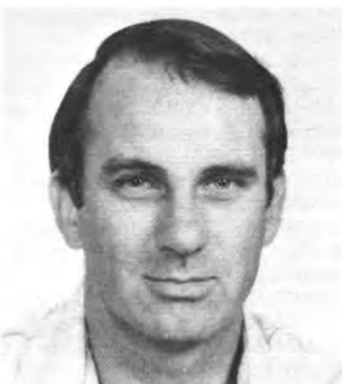

D.P. GALLEGOS (3743) 20

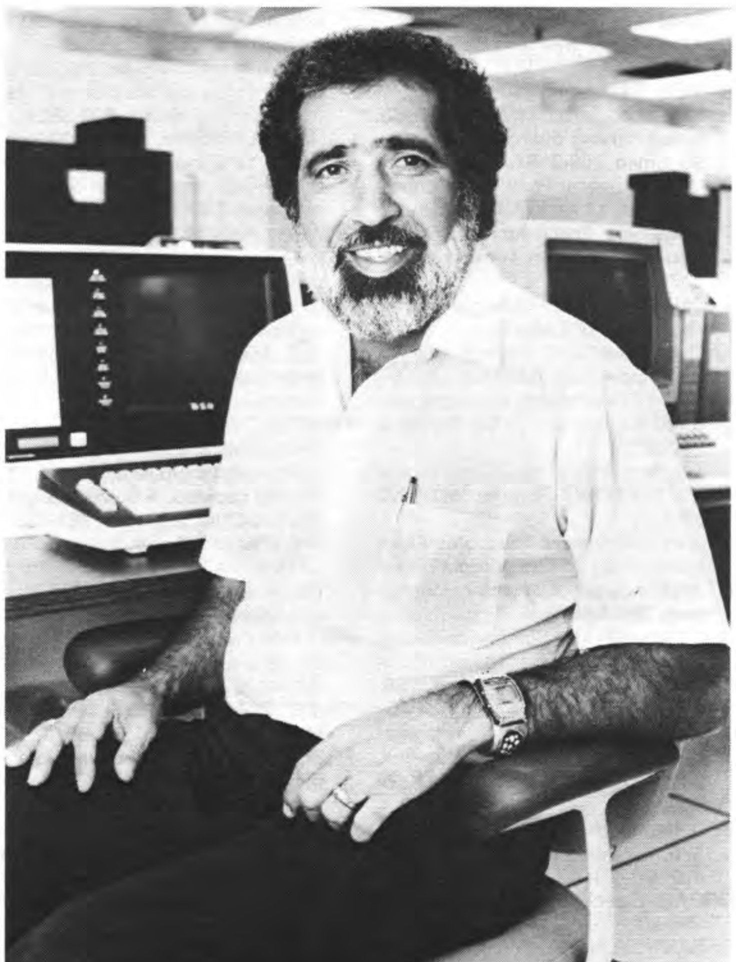

NADINE WILLIAMS (7522) 10


JIM MORENO (2541) 20


BRICK DUMAS (5310) 30


TERRY HERTHER (315) 25


ROB RINNE (8470) 20


JOE GONZALES (2631) 15

Key to Area Maps:

- ✚ — ***First Aid Station: Bldg. 831***
- ⬢ — ***Retiree Hospitality Area***
- ✱ — ***Handicapped Vehicle Entrance***
- ▲ — ***Open Gate; Information; Lost and Found***
- ◎ — ***Refreshments for Sale***
- ✪ — ***Shuttle Bus Stop***
- ⬅ — ***Entrance to Building***
- ← — ***Tour Route***

Continued from Page A

Food Service

Marriott Corp. will provide limited food service throughout the day beginning at 8:30 a.m.

Service areas will be located:

- outside Area I's gate 1 (second shift parking area),
- outside Area I's gate 10,
- Sandia Cafeteria (Bldg. 861),
- Area IV,
- Area V.

The menu available at Area I locations:

Nachos	$1.50
Hot dogs	1.00
Assorted chips	.50
Donuts/sweet rolls	.50
Coffee & soft drinks	.50

Limited menu in Areas IV and V:

Assorted chips	.50
Donuts/sweet rolls	.50
Coffee & soft drinks	.50

Parking

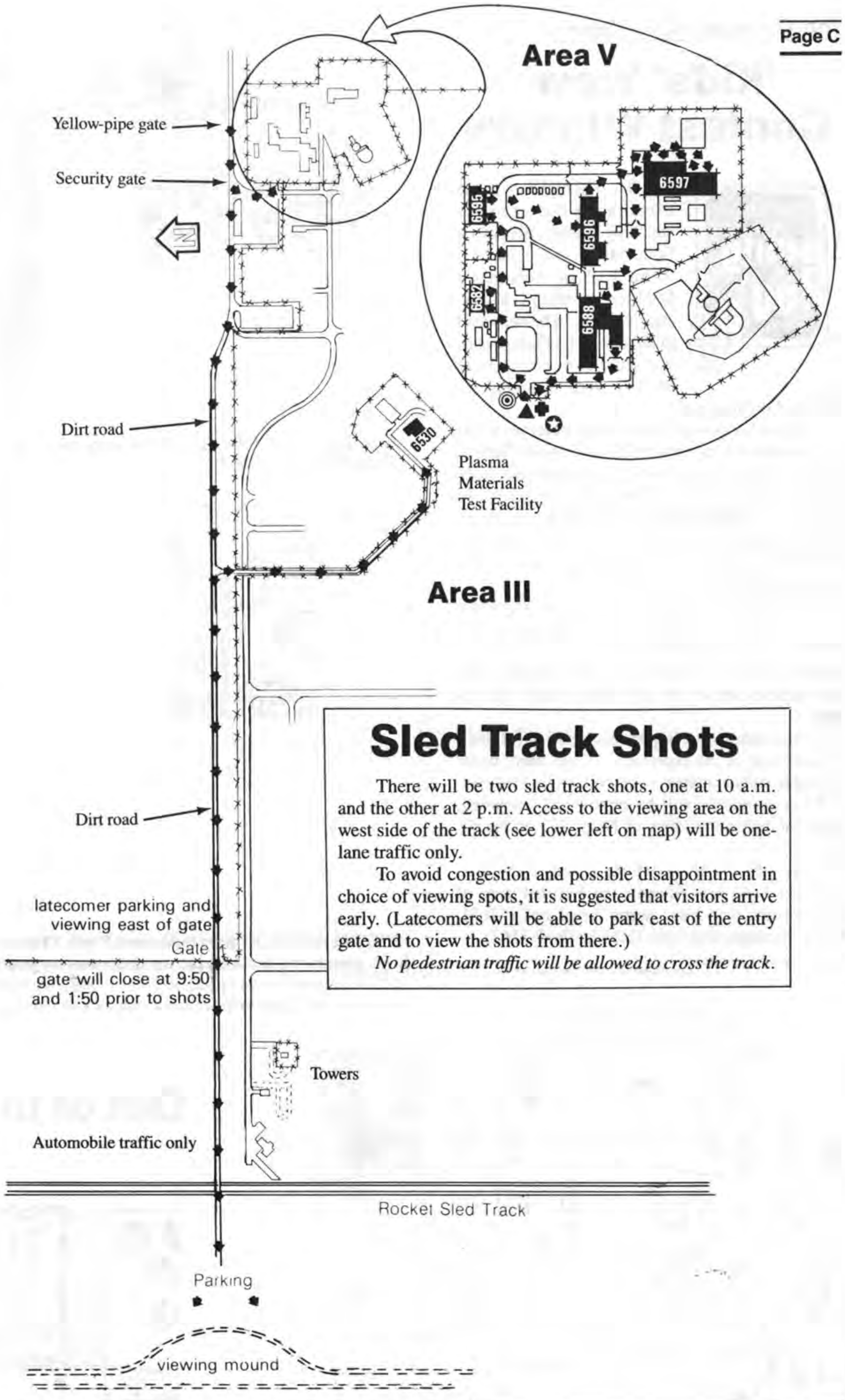
'Reserved' and 'Handicapped' spaces are not open to Family Day visitors.

All other parking areas will be open to visitors (including 'Visitor,' 'Sandian on Official Business,' and 'Car Pool' spaces).

Shuttle Bus

Shuttle buses will run every 15-20 minutes from Area I's gate 10 along the following route: Area IV, Area V, the Solar Power Tower, Area IV, and back to Area I (gate 10).

Shuttle bus service *will not* be available to the Sled Track viewing area.

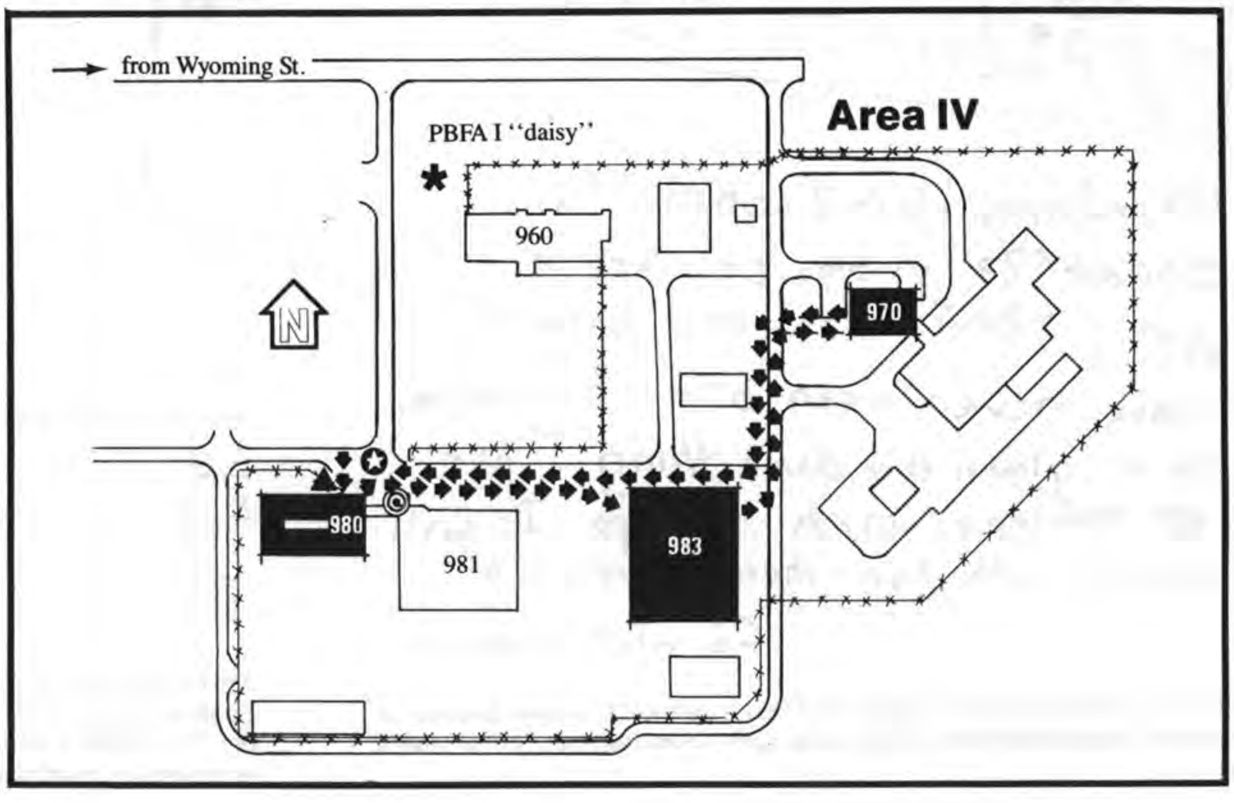


Sled Track Shots

There will be two sled track shots, one at 10 a.m. and the other at 2 p.m. Access to the viewing area on the west side of the track (see lower left on map) will be one-lane traffic only.

To avoid congestion and possible disappointment in choice of viewing spots, it is suggested that visitors arrive early. (Latecomers will be able to park east of the entry gate and to view the shots from there.)

No pedestrian traffic will be allowed to cross the track.



AREA III

6530		Plasma Spray Demo
Sled Track		2 sled shots (10 AM and 2 PM). Laser Tracker. Rocket Sleds/Videos

AREA IV

970	(Bridge)	Simulation Technology Lab
980		Posters. RAD LAC. X-ray Laser and SDI
983		PBFA-II AII Level, DAS and C/M and Posters

AREA V

6582		Hospitality Center and General Av. Info.
6588	10	Steady State Operation of the Annular Core Research Reactor
6595		Self-Controlled Maintenance Robot on a mock-up of SPR-III
6596		HERMES-II Facility Open w/Posters. Speed Cell
6597		Proto II Area. Open w/Posters

MANZANO

9981		Lobby & Solar Thermal Test Facility (Power Tower)

Top Three and Then Some

'Kids' View' Contest Winners

The three prize winners of our Family Day art contest are: Amy Mueller, Bernadette Benavidez, and Charlotte Ward. Each of them gets a $50 (mature value) U.S. Savings Bond — to be delivered to the parent by Family Day. The children's renditions of life and work at Sandia are published on this page.

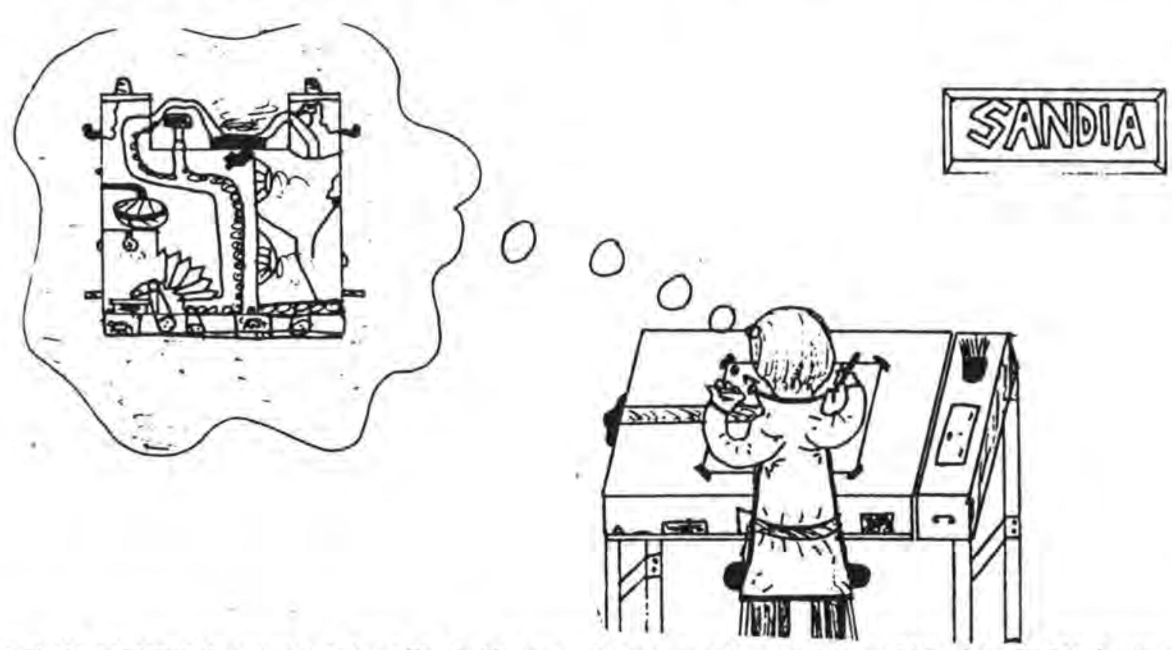
One of the remaining drawings deserves a special mention for its caption. Four-year-old Pamela, daughter of Leonard Duda (6241), narrates this image of Dad: "Daddy works & types on a computer, and he goes to another city to work with a long thing. Sometimes he be late. He works with a radar tool and tries to get it fixed, and walks on rocks." It's the last part that has us intrigued!

One other drawing, by Michael Shutt, impressed the judges enough to finally melt the heart of LAB NEWS editor Bruce Hawkinson (3162), who has agreed to publish it as well, despite the stringent space requirements for an already macroscopic special issue.

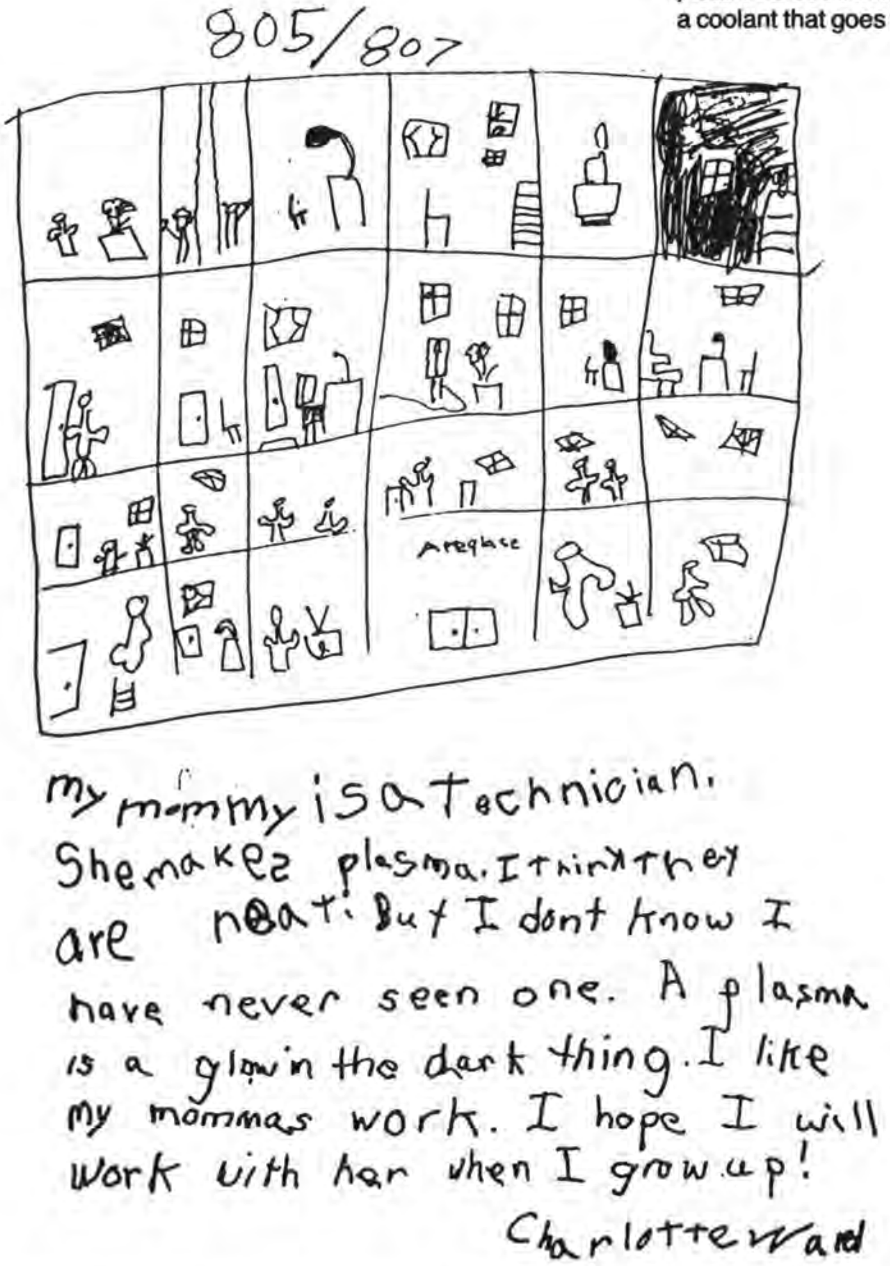
These same space requirements prohibited printing any more of the expressive — and fairly wide-ranging in subject matter — art collection. However, all 20 or so entries will be reproduced, mounted, and exhibited in the lobby of Bldg. 802 on Family Day.

The judges, a panel of three calling itself "Raters of the Lost Art" (despite the fact that none of the drawings was lost), were: Joe Laval (3163), Randy Montoya, and Irene Dubicka (both 3162).

STRAIGHT AND SIMPLE: "My mommy gives badges to people," writes 7-year-old Bernadette, daughter of Cathy Benavidez (3437).

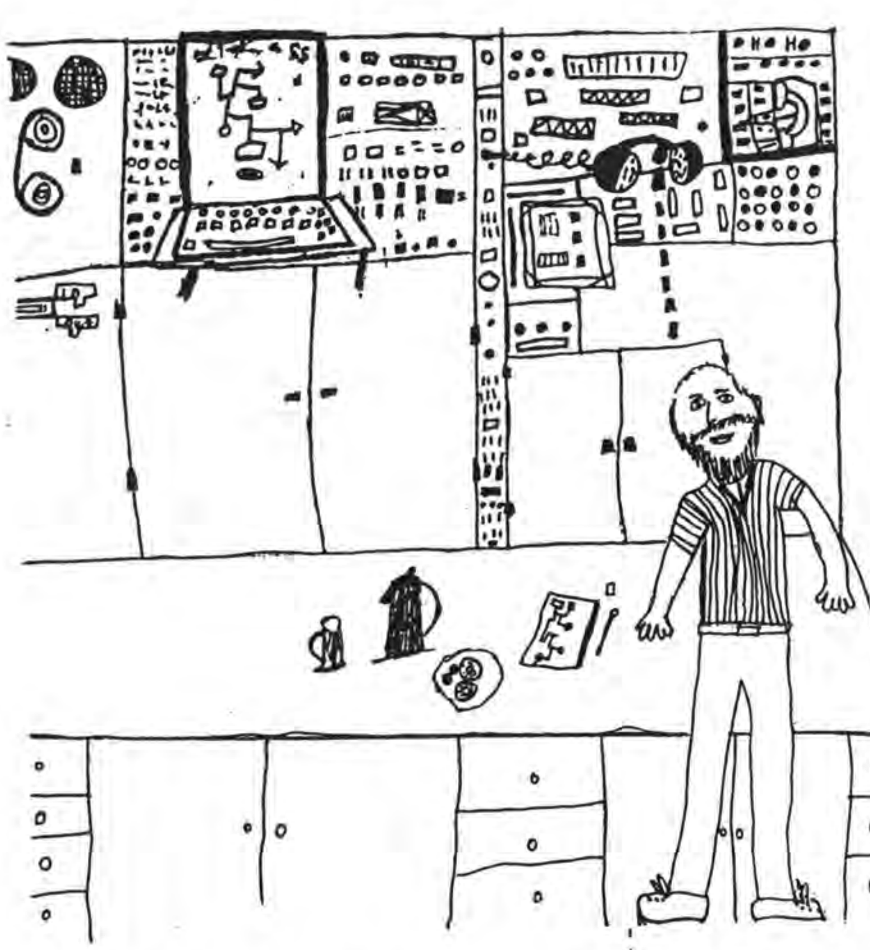


SPECIAL MENTION goes to Michael Shutt, 13 years old and grandson of Edward Neidel Jr. (2361). Michael's own caption reads: "This picture describes my Grandfather at Sandia drafting the pieces that go to build the picture he see's in his head. He drafts these pieces at a drafting table at Sandia. He drafts this machine which is a coolant that goes to the nuclear reactor which makes energy."



WE COULDN'T HAVE WRITTEN IT BETTER: 7-year-old Charlotte, daughter of Pam and Charlie Ward (both 1812), wrote out her own description of her Mom's work.

Out of the Pens of Babes . . .



'MY DAD IS A ELECTORNIC ENGINEER,' writes 11-year-old Amy, daughter of Geoffrey Mueller (2341). "He gos on lots of trips to test things. Hes no. 1 in his Div. The picture I made is from what I remember last time sandia had a day when families could come see inside. My Dad can keep lots of secrets."

Continued from Previous Page

Management Shifts

President of Energy Programs 6000, effective Nov. 1.

Dan joined Sandia at Livermore in 1968 as an aerodynamicist and worked in the application of laser Raman spectroscopy to gas flow studies. "I came in at a time when new hires were told that they had to create a research program," he says. "The combustion program came out of that. It's something I'm very proud of."

In 1972, Dan was promoted to division supervisor. He was named to head the Combustion Sciences Department in 1977, and became director of Combustion and Applied Research in 1983. Dan is the first VP to come out of Livermore.

Dan was a research fellow at the vonKarman Institute in Brussels, Belgium, before he joined Sandia. He has a BS, MS, and PhD in aerospace engineering from the Georgia Institute of Technology. "I was a senior in high school when Sputnik came along," he says. "That's what made me want to go into aerospace engineering."

Looking ahead to his position as head of Sandia energy programs, Dan says, "Energy programs will have to turn around in this country. The problems are more complex than they were 10 years ago. I'm excited about being involved in helping to solve them. I admire the staff in my new organization, and I'm enthusiastic about their potential work."

Dan is the U.S. Technical Representative to the Combustion Research Group of the International Energy Agency. He is a member of the planning committee of the Cooperative Automotive Research Program for DOT/DOE/NSF and a member of the American Institute of Aeronautics and Astronautics, the American Chemical Society, and the National Research Council. He serves on the Board of Directors for the Combustion Institute, and several review committees for NASA, LBL, NSF, and LLNL. Dan is the editor of *Efficient Use of Energy/The Role of Physics in Combustion* and the associate editor of *Experimental Diagnostics and Astronautics*.

THREE OUT OF FOUR of Bonnie Skenandore's (3155) pictures placed at the 1986 State Fair. Of the bottom two, "Penny" (left) placed third, and "Walt's Pots" placed first in the Indian Arts competition. The top two were entered in the Fine Arts competition, and "Santana Santa Domingo" placed fourth. "Unintimidated" (the one Bonnie's holding) didn't place but turned out to be a favorite. It was the one that sold.

What Happens Nov. 1?

Sandia's reorganization on Nov. 1 affects many people and organizations, and results in some top-management shifts. Looking at management changes first, here's what happens:

- Orval Jones (Defense Programs 5000 VP) promoted to EVP 20, replacing Tom Cook, who's retiring Oct. 31.
- Everet Beckner (Energy Programs 6000 VP) moves to VP 5000.
- Dan Hartley (Combustion and Applied Research 8300) promoted to VP 6000.
- Roger Hagengruber (Systems Studies 300) promoted to VP Exploratory Systems 9000 (new).
- Bob Clem (Systems Sciences 1600) moves to Exploratory Systems Development 9100 (new).
- Leon Smith (Instrumentation Systems 5300) moves to Monitoring Systems 9200 (new).
- Ron Detry (Computing 2600) moves to Engineering Design 8200.
- Larry Bertholf (Exploratory Systems 8430) promoted to 2600.
- Peter Mattern (Combustion Sciences 8350) promoted to 8300.

Now that you have *that* down pat, we'll concentrate on organizational changes. First, the existing ones:

Organization 300 (Systems Studies) — All departments move to new 9000 organization.

Directorate 1500 (Engineering Sciences) — Adds an additional department (1550 Aerodynamics, formerly 1630). A division (Fluid Mechanics and Heat Transfer 1511) moves to new 1400 directorate.

Directorate 1600 (Systems Sciences) dissolved. One department moves to 1500 (see previous item), one department and a division (1640 Applied Mathematics and 1624 Embedded Computer Research) move to new 1400 directorate, and three departments move to new 9000 organization.

Directorate 5300 (Instrumentation Systems) dissolved. Both departments move to new 9000 organization.

Directorate 6200 (Advanced Energy Technology) — One division (Intelligent Machine Systems 6228) moves to new 1400 directorate.

Still with us? Then let's take a look at the new groups.

Computer Science and Mathematics 1400 (director to be announced) has two departments: Computer Sciences 1410 (manager to be announced) and Applied Mathematics 1420 (Gus Simmons). The Computer Sciences Dept. will have responsibility for intelligent machines, embedded computing, and parallel processing. Gus's group will handle applied and numerical mathematics work.

The 9000 organization, headed by Roger Hagengruber, has two directorates: Exploratory Systems Development 9100 (Bob Clem), responsible for special projects, advanced systems development, exploratory systems development, and advanced systems research; and Monitoring Systems 9200 (Leon Smith), responsible for space systems, space sensors, sensor systems, and monitoring technology. A separate department, Systems Analysis 9010 (Curtis Hines), reports directly to Roger.

And now, today's pop quiz . . . Who's the director of 2600?

Welcome

Albuquerque
Ronald Allman (1124)
Richard Brown (2634)
Robert Ghormley (314)
Bonnie Hardesty (132)
Eugene Hertel (2641)
Frederick McCrory (6451)
Christopher Reiser (1124)

Arizona
Brian Rutherford (7223)

California
Sudip Dosanjh (6425)

Colorado
Raymond Prior (5323)

Illinois
Paul Cahill (1811)

Indiana
Matthew Schultz (5143)

Iowa
Jonathan Rogers (7542)

Michigan
Jeffrey Rupert (2364)

Ohio
Michael Prins (5321)

Oregon
Timothy Buckle (5231)

Texas
Alfredo Baeza (321)
David Beck (6427)
Marion Scott (2531)

Continued from Page One

Tom Cook

be remembered, was once slated to be the Atomic Energy Commission's (AEC's) weapon production facility: "The Corporation" was to be operated by Western Electric, the Bell System's production agency. That was logical — weapons were to be built here (Bldg. 880 was to contain the assembly lines). Employees did not need advanced degrees.

But by the late 50s, the AEC had put together a production complex across the country, and Sandia saw that its future lay in R&D, specifically in the R&D necessary to convert a nuclear device from Los Alamos into a working weapon for the rapidly growing nuclear stockpile. That task demanded scientific and engineering talent and training, including a cadre of people with MS or PhD degrees. Hence, people such as Tom found themselves positioned at the front end of Sandia's major and profound evolution from production to R&D.

In 1951 Tom had just earned his degree from Vanderbilt and had to decide among five job offers. "A Sandia recruiter named Ken Erickson came to school just when I was finishing my degree," Tom recalled. "He presented the weaponization work to be done at Sandia as an important and exciting arena to work in.

"So the final choice was between Oak Ridge and Sandia," he said. "I'd done my PhD thesis with some people at Oak Ridge, it was near where I went to school, and I liked the people, so it would have been a logical choice. But Virginia and I decided to be venturesome and head for the Wild Wild West for a couple of years. We just never got back!"

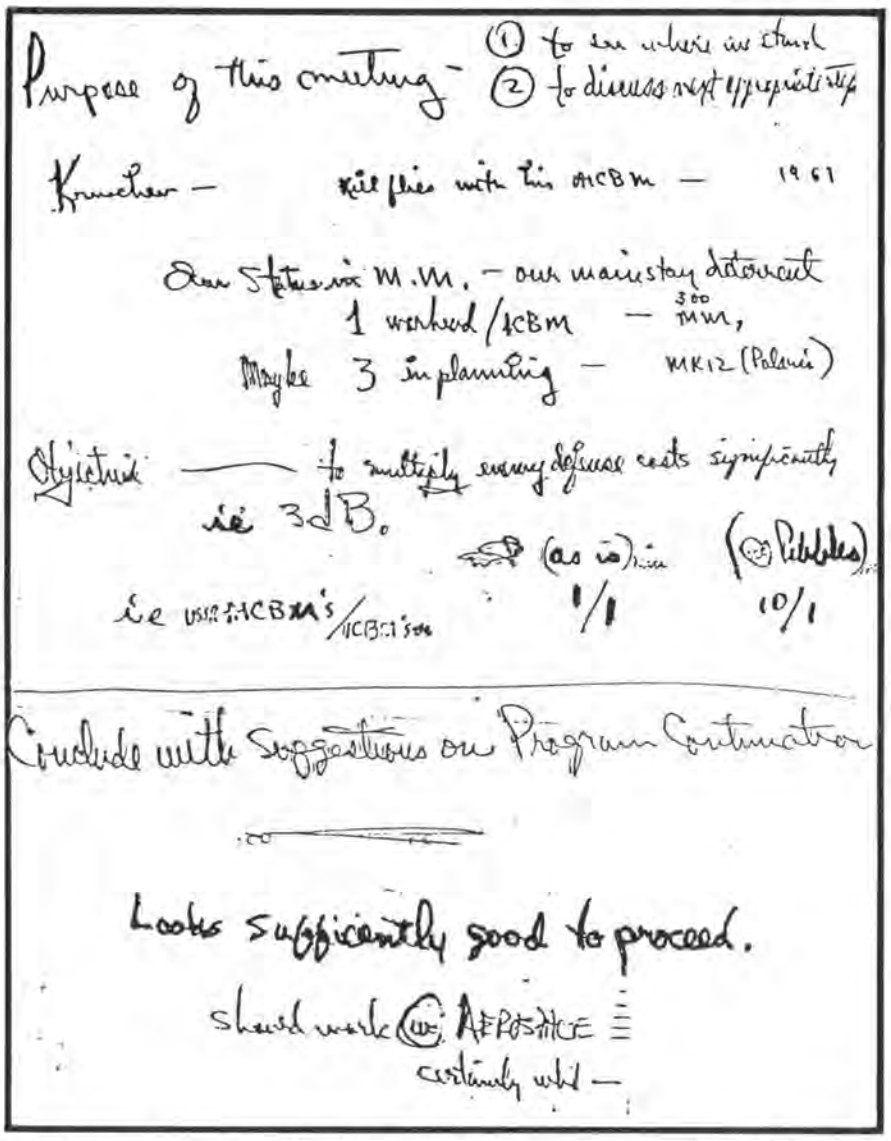
Tom was 24, the youngest PhD on the staff at the time and the youngest hired for several years thereafter. His scientific abilities and his managerial talents were recognized early: He became a section supervisor in 1955, division supervisor in 1956, manager of the Nuclear Burst Department in 1959, director of Physics and Mathematics Research in 1962, and Research VP in 1967. For exactly 14 years, Tom headed the Sandia Livermore Lab. And on June 1, 1982, he was promoted to executive VP. ("I guess the rise was pretty fast," Tom admitted. "But I've been leveled off at the VP level for 19 years.")

In terms of contributions to the nation's defense program, Tom first distinguished himself in the area of nuclear burst effects studies (commonly referred to as weapons effects) and became known in defense circles for his ongoing work in that field. "Working with several others in a department headed by Everett Cox, I focused on trying to understand the environments produced by the detonation of a nuclear weapon," Tom recalled.

"But we were doing more than that. We were, in a sense, trying to find a niche for ourselves as an AEC laboratory, one that would allow us to learn how nuclear burst environments would affect the nation's defense generally and our own product — nuclear weapons and their fuzing and firing systems — specifically. That was a good niche; it's still a major Sandia activity today."

From that period (the 1950s) came a document that's still a valuable reference tool in the field. Written by Carter Broyles (now 7100) and Tom, and known, poetically, as "The Cook Book" ("Carter and I tried to find a person named Fry to include as an author so we'd have Cook, Broyles, and Fry, but there wasn't one at Sandia"), it defined nuclear burst effects from ground level up to 100,000 feet. "In those days, 'high altitude' meant 30,000 feet," Tom pointed out. "To extrapolate burst outputs up to 100,000 feet was a rather radical thing to do in those days. Our critics thought it was esoteric and unimportant to the world."

Along came Sputnik, in 1957. Suddenly, 30,000 feet was no longer "high altitude." Sandia had already made plans to do a nuclear test in space. "I went with Ed Stewart [Albuquerque Operations Office] and a couple of colonels from DMA [the AEC's Division of Military Application] to Redstone Arsenal and arranged with Wernher Von Braun to put a nuclear device on top of a Redstone missile



THESE EARLY NOTES were scribbled by Tom Cook at a meeting that led to Sandia's involvement with Pebbles, the first nuclear weapon program to use the MIRV (Multiple Independently targeted Reentry Vehicle) concept. Notes are cryptic and reproduction is poor, but see references to Khrushchev's boast that he could "kill flies with his AICBM [anti-ICBM]," to "M.M. [Minuteman] — our mainstay deterrent," to "Objective — to multiply enemy defense costs significantly" by perfecting the development of several small warheads carried on one missile, and the prophetic "Looks sufficiently good to proceed" note near the end.

and detonate it in space," said Tom. "In fact, we did two high-altitude shots, Teak and Orange, in 1958." (Teak was detonated at 75 km, almost 50 miles, or about 250,000 feet, up; Orange at 50 km, about 30 miles.)

Gathering data from those shots demanded small rockets to carry instrument packages aloft. "As a result of that effort by our aerodynamics people, Sandia began a long-lasting involvement in the small-rocket business," Tom noted. "We're known for Strypi, but we've done some other very good work for the country in that area. And I hope we'll be able to continue the development of SWERVE, our maneuverable RV concept, in the future."

Given the mid-50s threat of ICBMs (intercontinental ballistic missiles) carrying nuclear warheads, high-altitude effects tests were not conducted simply to add to the store of scientific knowledge. "People became quite interested in defenses against ballistic missiles, so we worked hard to try to understand how to neutralize enemy warheads over this country and how to make ours survive their defenses," noted Tom. "That went on until 1973, when the anti-ballistic missile [ABM] treaty was signed with the Russians. The same topic is, of course, controversial today — listen to any discussion of the Strategic Defense Initiative, 'Star Wars.' "

Throughout his career, Tom spent much of his time traveling in connection with his service on several boards and panels that focused on the nation's defense. He chaired the Vulnerability Task Force of the Defense Science Board and was a member of others: the Air Force Scientific Advisory Board, the Scientific Advisory Group of the Joint Strategic Target Planning Staff, the DoD Scientific Advisory Group on Effects, the Steering Task Group of the U.S. Navy Strategic Projects Office, and the Air Force Penetration Program Panel.

For several years during the height of this activity, most of it centered in Washington, Tom was flying 100,000 or so miles a year, and, as Tom put it, "that calculates to an 'average velocity' of 10 miles an hour."

But the trips to Washington and other destinations were far from executive perks. "It's important to have windows into the rest of the technical world, and particularly into the Defense Department," Tom said.

"And it still is important that Sandia understand not only the functions that DOE is responsible for, but also understand the broader issues so that we can do a good job for the country."

Out of that "broader issues" concern at Sandia came a revolutionary weapon concept: putting several warheads on one missile. Originally called "Pebbles" (apparently from the fact that a person could throw only one rock at a time — but several pebbles), and later code-named Halberd, it grew into what is now known as MIRV (Multiple Independently targeted Reentry Vehicles).

The idea was that if Sandia brought together all its new technologies, it could design a nuclear warhead-carrying RV in the weight and volume commonly assigned to decoys. "I was a consultant to Aerospace [one of the DoD contractors involved] in the early 60s, so I knew the improvements the DoD was making in missile and guidance technology," Tom explained. "I also knew that developing very small RVs with small arming, fuzing, and firing systems was a pretty good technological challenge. But we made them work. The first MIRVed weapon was the Mark 3 for the Poseidon missiles carried by the Polaris sub. This system combined the new DoD and AEC technologies and thereby multiplied the effectiveness of each Poseidon many times.

"Some defense critics think MIRV was a poor idea, but it was either do that — and multiply the effectiveness of our missiles — or build larger missiles and more of them, as the Soviets did."

Another example of the benefits of windows into the technical world grew out of "a 1959 Air Force Scientific Advisory Board report that first delineated the problem of gamma ray transients and their effect on military systems," noted Tom. "I was chairman of that study group, which included Nobel Prize winners Bill Shockley and Charles Townes as well as Ken McKay, former executive vice president of Bell Labs.

"The gamma ray concerns led to our development of machines to test our designs for their response to pulsed radiation environments. In 1964, the first of these machines, Hermes I, produced 25 rads of radiation in a sub-microsecond pulse. Then came Hermes II, which came on-line just before I went to Sandia Livermore; it would produce 10,000 rads in an even shorter pulse.

"And these early 'simulation' machines were the forerunners of Sandia's now internationally prominent pulsed power capabilities, epitomized by PBFA II. These capabilities offer super excellent 'nuclear weapons effects simulation' and are also being applied to production of energy from fusion in a controlled

(Continued on Next Page)

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manner and to potential particle beam weapons for Star Wars.''

Still another example: ''Carter Broyles and I went to Los Alamos and visited their pulsed reactor and decided we really should have that capability here. Bill Snyder [now 6400] was involved in the early work, which has now evolved into a first-class pulsed reactor facility'' in Area V.

A similar case grew out of a report from the Defense Science Board Vulnerability Task Force that Tom chaired. The report raised serious concerns about the survivability of missiles and satellites in space if they're exposed to nuclear radiation. Sandia was already concerned about whether electronics in nuclear weapons could survive burst effects; these concerns led to the excellent capability Sandia has developed in producing radiation-hardened circuits.

Research Management Too

Once the single-minded push to build the stockpile had ended (late 50s), Sandia turned its attention to its goal of becoming a ''real'' R&D lab. ''I was involved with that effort when [then President] Julius Molnar from Bell Laboratories started us on that path,'' said Tom. ''He instituted the Bell Labs hiring policies for the technical staff — ''masters degree or better'' was established as a requirement for joining the MTS ranks. That was a revolutionary thing in those days.

''And when Molnar left, Monk Schwartz [1960-66] followed through on that approach. After all, if you're going to do high-quality research and development, you're going to need people trained at that level.

''And it worked. We have succeeded in becoming an internationally recognized research and development laboratory with a staff as good as you'll find anywhere in the kinds of science and engineering that are important to Sandia.''

While Livermore VP, Tom established an applied research capability for that lab. During his tenure, Sandia became internationally known for its research on tritium and on combustion.

And it was while Tom was at Livermore in 1971 that the AEC honored him with the prestigious E. O. Lawrence Award for the nuclear effects studies he had conducted back in Albuquerque and for the spinoffs from those studies.

Some Fond Memories

Asked about his greatest career satisfaction, Tom instantly replied, ''The 14 years I spent at Livermore. While I was there, Sandia Livermore changed from a project support lab for Lawrence Livermore to a high-class R&D lab. It achieved major status in science, in tritium handling, and in combustion research. I'm quite proud of that. And Dick Claassen has done a great job of maintaining its status.''

Tom's toughest period? ''The time that the Soviets broke the testing moratorium in September 1961 and fired the largest nuclear weapon ever detonated by anybody, the 60-megaton weapon that Mr. Khrushchev boasted about. It had been a three-year moratorium, so we had to scramble around to put our testing teams back together. We'd been caught flat-footed. It was a very, very busy year.''

Tom's most memorable day? ''That's easy. It was the day of the Teak shot. It was fired 50 miles up, in the atmosphere. That turns out to be a region in which you excite all sorts of chemical species and produce an artificial aurora borealis. I was on a carrier right under it when it went off — very safe, right under it. Just spectacular!''

Next, Retirement

Tom and Virginia plan to spend some time relaxing in their condominium on Maui, after they move back to the house on Pleasanton Ridge they left behind in 1982. Tom plays tennis and golf, and he just might take up oil painting again — ''With a palette knife. You can make mistakes and erase them; just scrape off the thick paint and put some more on. It's nice to be able to wipe out mistakes.''

He's considered writing, and he has a safe full of documents on his experiences to draw from. ''But the problem is that most of them are classified,'' he noted. ''And even though they now really should be declassified, you can't declassify a document originated by someone else; and in most cases the originator, and often the originating organization, is no longer available. It's a real bureaucratic Catch-22.''

But, most of all, Tom is looking forward to some consulting: ''I'm really interested in arms control issues, especially those that involve nuclear weapons. I believe that we can look forward to some serious negotiations in the next few years. It's an exciting time, and I want to be a part of it.'' •BH

Model of Executive Vice-President

FORMER PRESIDENT GEORGE DACEY

IN HONOR of Tom Cook's impending retirement, former President George Dacey and his friends Bill Gilbert and Art Sullivan created a ballad, based on Bill's and Art's "Model of a Modern Major-General." George introduced the new work (from which one stanza and chorus follow) last month at the Large Staff Conference.

Stanza I

He is the very model of Executive Vice-President,
On atomic information he's Sandia's guru-resident;
He knows effects of weapons and all the tests historical
From Trinity to Misty Rain, in order categorical;
He's very well acquainted, too, with matters mathematical,
He understands equations, both the simple and quadratical,
About binomial theorem he's teeming with a lot of news,
With many cheerful facts about the square of the hypotenuse.

Chorus

With many cheerful facts about the square of the hypotenuse,
With many cheerful facts about the square of the hypotenuse,
With many cheerful facts about the square of the hypote- pote- nuse;
He's very good at integral and differential calculus;
He knows the scientific names of beings animalculous;
In short, in all his expertise, with which he's never hesitant,
He is the very model of Executive Vice-President.

Some Philosophical Highlights

• It was under President Eisenhower, during my early days at Sandia, that the nation recognized its reliance on nuclear deterrence as its basic national policy. The basic idea is that we [as a nation] really felt, at that time, that we couldn't compete with the Soviets in numbers of troops and conventional weapons.

• Now, of course, people would like for nuclear weapons to just go away. It's not that easy. But the U.S. needs to negotiate with the Soviets on arms control issues.

• Sandia's real product is more determined by national policy than by military requirements. It's really the policymakers that determine what we need to do in the way of nuclear weaponry.

• Today Sandia proposes new [nuclear defense] possibilities, but we don't push them as much. We tend to go along with the requirements of the system, and those requirements tend to be simply minor improvements in things we already have.

• We can do some things now in technology that would make a substantial, even revolutionary, difference in our nuclear deterrence capabilities. But the nation's current syndrome seems to be ''If it's new and it's nuclear, it's bad!''

• All of us would like to do away with nuclear weapons. But that has to start with some substantial reduction in real arms [by both the U.S and the U.S.S.R.]. And the treaty has to be businesslike, one that can be verified.

• All during my career, we considered ourselves a part of the government, a real national laboratory, not just another contractor, and not in funding competition with industry, but focusing on our mission of safe and reliable nuclear weapons. Now we're involved in a lot of other activities, commonly known as reimbursables, which is work for non-DOE agencies. We must not lose our focus as stewards of the nation's nuclear capabilities.

• I think there is a specialized niche for Sandia as a national laboratory. Many of us came to work here not to get rich but because we thought Sandia has an important job to do.

• Technically, we can and should compete with anybody in the fields we're in. I'm all for technical competition. But if we compete for contracts, we're going to end up just like other big industrial groups around the country.

• The problem is whether we are motivated to bring dollars into the company or whether we are motivated to do things of importance to the nation. Sandia must continue to be motivated to attack problems of national importance.

• We have a broad spectrum of capabilities, which allows us to do a lot of things well.

• I think the Sandia niche has to be very delicately balanced between universities — we don't want to compete with them for money and yet we do want to compete with them technically because we want to be right in the forefront of the sciences that we're involved in — and industries.

• If we do too much work for the Department of Defense, there will again be the question, ''Why aren't we in the DoD?'' I've always believed that it's in the nation's best interest for us not to be in the DoD just so that we can maintain our technical excellence and some independence of evaluation.

• On motivating people: You've got to have good technical challenges. And the job needs to be important to the country. •TBC

Travel Addicts, Here's Your Chance!

EIGHTY DAYS is exactly what it took for world-famous travelers Ed (2361) and Lu Neidel to circumvent the globe earlier this year, but Ed says no balloon travel was involved (sorry, Jules Verne). Even so, the Neidels had a great time, and they'll share their fabulous experiences and movies with all you travelphiles on Oct. 23 & 30. Part I on the 23rd covers exotic places like Australia (koalas, anyone?), Indonesia, Singapore, and Thailand. You'll have to wait until the 30th to learn about India and parts of continental Europe, including Germany, Switzerland, Italy, and France — including that *extraordinary* May Day dinner in Paris. Both sessions start at 7:30 p.m. in the ballroom. Some of us may never make that round-the-world trip, but here's a chance to get some vicarious kicks!

SINGLES TAKE OVER the Club next Thursday, Oct. 16, in celebration of — what else? — Indian summer. We've heard a lot of excuses for celebrations, but this one may take the cake. Anyway, it all starts right after work with free munchies from 5-7 and special-price drinks, along with 50-cent draft beer. From 6-10, it's Graffiti providing the dancing music. Come on out and meet some of the friendliest people in town.

WESTERN FLYER IS NOT a choo-choo train; it's a group that really belts out that country/western beat. And it'll be on hand next Friday night (Oct. 17) to make music for all you stompers. Before the stompin' starts (at 8 p.m.), plan to take advantage of that two-for-one dinner special featuring prime rib or fried shrimp — your choice of two entrees for the bargain-basement price of $14.95. Find out about the other good stuff on the menu when you call for reservations (265-6791).

GREEN CHILE AND HAM sounds like a book title, but don't be fooled. These are just two of the culinary delights that'll be served up at the next Sunday brunch on Oct. 19. They'll be available from 11 a.m.-2 p.m., along with other goodies: sausage, baron of beef, scrambled eggs, hash browns, fruit salad, salad bar, and fruit juices. And the best news of all — the buffet costs only $4.95, with kids under 12 half price. It's the best brunch deal in town, but judging by the hordes of people that turn out for these things, you must already know that.

NO UNDER-THE-TABLE DEALS when those T-Bird card players get together; rest assured of that. Here's a group that really knows how to have a good time, and they're getting together this month on Oct. 16 and 30 (both Thursdays). The action gets started both days at 10:30 a.m. There's a rumor afoot that one of these stalwart shufflers has written a "Beat the Dealer" book; wouldn't surprise us a bit.

OTHER T-BIRD NOTES: Those free-wheeling RVers are set to take off for Santa Rosa Lake State Park Oct. 28-30. If you need more caravan info, call wagon masters Tom Brooks (344-5855), Bill Minser (299-1364), or Andy Railey (898-0519).

New T-Bird officers and the Board of Directors get together for a 2 p.m. meeting on Monday, Oct. 20. This means you, too, committee chairmen! All Thunderbird members are welcome.

OCTOBER'S A BUSY MONTH for Coronado Ski Club types, even though there's no snow yet (at least *not* when *this* was written). The Club holds its monthly meeting on Tuesday, Oct. 21, at 7 p.m. Happy Hour starts at 6:30, and the word is out: As usual, some fabulous door prizes will be given away that night. Representatives from that outstanding ski area, Purgatory, will be on hand to tell you all about it.

Two nights later (Oct. 23, 7 p.m.) the Ski Club sponsors its annual ski clinic to bring people up to speed on how to buy used schussing equipment (a good thing to know if you plan to pick up some bargains at the Ski Swap the following weekend). Danny Fowler of Action Sports is the speaker.

IT'S NO ENGLISH PUB, but the C-Club, in the best of pub tradition, is putting together dart leagues for both beginners and the more advanced types. We hear tell that the game of darts is all the rage these days, so be the first one on your block to get involved. Club manager Sal Salas is the honcho on this one; give him a call at 265-6791 for more info.

PHASES OF THE MOON must be right for stompers and shufflers this month. Those popular Poor Boys from Isleta will be doing their thing (that is, making c/w music for your dancing pleasure) on Oct. 24 from 8 p.m.-midnight. Super menu selections on the two-for-one dinner that night, too: filet mignon or fried scallops. Better call in that reservation right now.

WEAR THAT STRING OF PEARLS and get in the mood for Saturday night swing time on Oct. 25, featuring Don Lesman and the crew with the Big Band sound. Plan to make a night of it; before the dancing starts at 8 p.m., a two-for-one dinner special — prime rib or fried shrimp for $14.95 — is available. (Two-for-one on Saturday night? What is this world coming to?) Crowds pour in when they know that smooth music from the 40s and 50s is on tap. You've been warned — make an early reservation!

THE GOBLINS'LL GITCHA if you don't watch out . . . and they'll all be at the big haunted house party on Sunday, Oct. 26, from 5-9 p.m. This one gives the kids a head start on Halloween. There'll be games throughout the evening, scary movies, and, of course, that spooky haunted house to explore. The little gremlins will love the low-cost buffet featuring hamburgers, hot dogs, and much more. So dust off those costumes and join in the fun. It's limited to members' children only, and there's a $1 admission charge. That famous C-Club "green card" should be shown at the door as well. More details next issue.

IF YOU HAVEN'T JOINED those Monday night revelers who watch their favorite football teams perform on the big screen at the Club lounge, you're missing one heck of a party! Behind the bar, Joe serves up 50-cent draft beer and free munchies all night long. And that's not all — prizes are given away at halftime. To get in on all this merriment, just show up at the Club any Monday night around game time.

Take Note

Philatelists will be having some phun on Phamily Day weekend. ALPEX, the Albq. Philatelic Society's fall exhibition, will be held Oct. 17-19 (12 noon to 8 p.m. on Fri., 10 a.m. to 8 p.m. on Sat., and 10 a.m. to 5 p.m. on Sun.). Admission is free and hourly door prizes will be offered. The exhibit site at the Holiday Inn-Midtown has room for 15 stamp dealers and 60 frames. The U.S. Post Office will have a table with recent issues. Sandians who organized the stamp show were Bill Pepper (ret.), vice-president of the society; William Cocke (7231); and Pete Kaestner (1636). For more info, call Pete at 6-0147.

Death

Etheleen Charley of Projects and Contracts Section 7861-1, died Sept. 26 from injuries suffered in an automobile accident. She was 34 years old.

Etheleen had been at the Labs since July 1979.

She is survived by two children.

Fun & Games

Bowling — Attention, roundballers! Don't forget to send your SANDOE Bowling Assn. membership fee of $2 to Dora Gunckel (6410). Membership lets you bowl in the SANDOE fun tournaments (No Tap, Scotch Doubles, No Tap/ Scotch Doubles, or Best Ball). You'll also be eligible for the Bowler-of-the-Month award that paid $18 last year. There are four winners each month (two men and two women), both scratch and handicap series. Your series can be bowled in any sanctioned league.

The tournament schedule is as follows:

Oct. 11-12	4-Game No Tap	Holiday Bowl
Nov. 15-16	Scotch Doubles	Fiesta Lanes
Jan. 17-18	No Tap/ Scotch Doubles	Holiday Bowl
Feb. 7-8	Best Ball	Holiday Bowl
March 14-15	4-Game No Tap	Fiesta Lanes
April 11-12	Scotch Doubles	Fiesta Lanes

Officers for the 1986-87 season are: Jerry Long (7111), president; Fidel Perez (7481), vice president; Dora Gunckel (6410), secretary/treasurer; Lil Radtke (3430), women's representative; Wayne Yoshimoto (7474), men's representative; and Margret Tibbetts, tournament director.

IN THE RUNNING at the Duke City Marathon '86 were (from left) Pete Egan (3330), Lisa Dunckel (3321), Gwen Gorman (3320), Kate Washburn, Susan Harris (both 3330), and Juan Griego (3321). Kate won the woman's marathon in 2:46:06, beating her old record by almost 11 minutes. Pete also endured the whole 26 miles, Lisa ran the 5K race, while the rest — including walker Lynne Judge (3330), not pictured here — went for the half-marathon. The grapevine has it that, out of the 50 or so Sandian participants spotted at the day's events, Medical had the highest number of runners per capita of any organization.